Coordinating Institution— **Foothill College #2**
Contact Person's Name and Title
Peter F. Murray Executive Dean/President's Office
Contact Person's Email Address
murraypeter@foothill.edu
Contact Person's Phone Number
650.949.7486
Contact Person's Mailing Address
Executive Dean/President's Office
12345 El Monte Rd.
Los Altos Hills, CA 94022-4599

− List of Participants:
Foothill College
CSU San Luis Obispo/ College of Engineering
UC San Francisco
Fogarty Institute for Innovation

Foothill College has developed and adopted a set of innovative strategies dedicated to improving students' success at two-year college level, leading to increased achievement of four-year bachelor's degrees. These effective strategies will be extended in the next several years through partnerships with CSU CalPoly and industry partners.

Specifically, Foothill College has implemented innovative academic support services that are tightly integrated with STEM courses and pathways:

- providing mentoring for progressive student guidance,
- enabling increased academic growth,
- creating new (online and hybrid) STEM courses,
- offering a full complement of STEM courses all year, including summers,
- setting up internships and special programs,
- savings in cost of obtaining degrees through institutional research.

Foothill College program leaders identified these as particularly effective strategies for improving students' retention and completion rates, and a detailed, external evaluation has shown successful results beyond program benchmark. Many of these methods were developed in new practices applied during the past decade; all were instituted in the past year with new focused programs in the Foothill Physical Sciences, Mathematics and Engineering (PSME) Division.

Foothill College's increased offerings of STEM courses that directly articulate to UC and CSU STEM majors, and the increased preparedness of Foothill STEM students, significantly improve the likelihood that students will receive their Bachelor of Science degrees in four years instead of six years. In the coming years, Foothill College will be extending this model to other STEM majors as well as to other community colleges and state colleges.

FOOTHILL COLLEGE
OFFICE OF THE PRESIDENT

JUDY C. MINER

December 15, 2014

California Department of Finance
Education Systems Unit—Innovation Awards
7th Floor
915 L Street
Sacramento, CA 95814

To the California Department of Finance:

I assure that I have read and support this application for an award. I understand that if this application is chosen for an award, my institution will be required to submit, for approval by the Committee on Awards for Innovation in Higher Education, a report indicating proposed uses of the award funds and, as the fiscal agent, will be responsible for distributing funds to any other participating entities. I also understand that, if this application is selected for an award, my institution will be required to submit reports to the Director of Finance by January 1, 2018, and by January 1, 2020, evaluating the effectiveness of the changes described in this application.

Thank you,

Judy C. Miner, Ed.D.
President

1. Context and Goals

Foothill College has pursued and adopted a set of innovative strategies dedicated to improving students' success at the two-year college level leading to increased success in achieving four-year bachelor's degrees. Foothill's specific target goals are by 2020, to increase STEM students' success rate from 65% to 70%, to double the number of underrepresented students in STEM programs, and to increase STEM students that transfer into four-year bachelor degree programs by 5%. Foothill's strategic goals are to extend and improve the innovative methods which, so far through 2014, have met with continuing and increasing success. Those strategic goals notable include the following:

- Innovative academic support services that are tightly integrated with STEM courses and pathways.
- Scholarships and mentoring for progressive student guidance and an active learning community.
- New (online and hybrid) STEM courses created to articulate with University of California and California State University core STEM major courses.
- Full complement of STEM courses all year around, including summers, that provide opportunities for students from various universities and colleges to catch up with major requirements, stay on track and get ahead of their schedules;
- Internships and special programs to encourage students to pursue and persist in STEM majors, with priority focus on underrepresented groups.
- Saving in the cost of obtaining degrees through institutional research that allows close monitoring of student progress.

Foothill College program leaders identified these as particularly effective strategies for improving students' retention and completion rates, and a detailed, external evaluation has shown successful results beyond program benchmark goals. Many of these methods were developed in new practices applied during the past decade; all of the methods were instituted in the past year with new focused programs in the Foothill Physical Sciences, Mathematics and Engineering (PSME) Division. In early 2014 PSME concentrated a set of strategies first in its Mathematics program, with detailed plans to expand the methods throughout the college, starting with Computer Science, Biology, and a new Biomedical Engineering program, and then expanding through PSME programs and then the entire college. Evaluation measures have shown that the PSME innovations are now raising the success rates of average residential students toward the level of the most self-motivated students, and are also raising the success rates of underrepresented students toward the (rising) institutional average.

The application, timing, and ongoing evaluation of Foothill College's innovative methods in increasing student success rates toward achieving four-year bachelor degrees are monitored under a program plan developed and actively applied by the Foothill PSME Division. Several successes, and some substituted practices, and some new added strategies are measured and given feedback for improvement by both Foothill internal evaluation and by independent external evaluation.

2. Student Population Factors

Table 1 describes Foothill College Physical Sciences, Engineering and Math Statistical Profile in 2013-2014 academic year. The ethnicity list is dictated by California CCC. Table 2 provies information on the proportion of students who are forster yough, students with disabilities, low-income students and veterans in the Fall of 2013.

Table 1	Enrollment	Percent
African American	959	4
Asian	8780	34
Filipino	1088	4
Latino /a	4358	17
Native American	130	1
Pacific Islander	282	1
White	7319	28
Decline to State	2875	11
Female	10,752	42
Male	15,039	58

Table 2	Unduplicated Head count
California Work Opportunity and Responsibility to Kids	25
Cooperative Agencies Resources for Education	12
Disabled Students Programs and Services	789
Exntended Opportunity Programs and Services	281
First Generation	3,511
Foster Youth	161
Middle College High School Program	63
Military (Active Duty, Active Reserve, National Guard)	20
Puente	81
Special Admit	464
Veteran	327

STEM student FTES is 3,564 or 27% of Foothill's total FTES for 2013-2014 AY. The Physical Sciences, Mathematics & Engineering division (PSME) contains most STEM courses at Foothill. Student success rate for PSME is 65% and for Foothill as a whole is 77%. For African American, Latino, Filipino populations, success rate is 51% and 69% respectively. Note the PSME "Decline to State" is 11%, which often adds to the underrepresented categories.

From 2011 to 2014, at Foothill College the reported Latino ethnicity group has **increased** from 18% to 21%.

In the last four years, the enrollment at Foothill College decreased from 133,048 to 127,546 while the enrollment in Physical Sciences, Mathematics and Engineering (PSME) Division has **increased** from 16,184 to 25,791 (59% growth).

In the last four years, the enrollment in engineering courses **increased** from 247 to 393 (59% growth).

In the last four years, enrollment in bottleneck engineering courses has **increased**, due to more frequent and continuous offering of those courses. For example, Introduction to Circuit Analysis was offered every quarter, Winter 2013-14 through Fall 2014-15; in 2013, it was only offered two out of the four quarters. Properties of Materials enrollment **increased** 60% and the success rate **increased** from 84% to 88%. Introduction to Circuit Analysis grew 9% and the success rate **increased** from 79% to 89%. Statics enrollment **increased** 153% and the success rate **increased** from 71% to 76%. The course success rates in Introduction to Engineering have **increased** from 65% to 88%. Females have successfully completed the course at increasingly **higher rates** between 2010-11 and 2013-14 (33% to 80%).

In the last four years, the success rate of Latino students in engineering courses has **increased** from 61% to 77%.

Factors that affect the ability of Foothill STEM students to earn bachelor's degrees, graduate within 4 years, and transfer, including the particular factors that disproportionately affect student groups that are underrepresented in higher education, including these:

1) Students must spend a large part of their time in employment to support themselves, reducing their time on task and concentration on academic progress. **Foothill has significant financial support programs as well as over 20 full STEM scholarships ($4,200/year).**
2) Foothill College served 25,640 unique students during the 2011-12 academic year; the college's enrollment in Fall 2011 was 15,500, of which 4,508 were full-time students. 2,474 were STEM students, of whom about half were first-year STEM students, and 45% of those were full-time students, so about 557 students would have been academically eligible to apply for a scholarship. Available figures of financial standing show that 34% of students were in families with under $25,000/year total family income. This leads to a high estimate of 189.
3) New (freshman) students are underprepared in STEM courses, in particular math. They are improperly placed and have gaps in their knowledge. There is also the issue of mindset, not "college ready". Since Foothill accepts 100% of all students that apply, the spectrum is quite broad. **Foothill has created a series of scaffold programs to address this issue described in other sections. There is no one "silver bullet".**
4) The African Americans, Latinos, Filipinos student population success rate is 17% (51% versus 68%) lower than the non-targeted students for both PSME and MATH (48% versus 65%). This population also has a much higher level of withdrawals (W). (Further details available from Foothill College; see PSME_MATH-profile.pdf.)
5) Students have very complex lives. This includes a family (underrepresented) that does not appreciate education/degree, incarceration, unwed parents, being the care giver. The list is endless. **The students are provided various forms of support but cannot be significantly influenced by changes to policies, practices, or systems. Our anecdotal estimate is this is 13% of STEM students.**
6) Articulation and pathways for transfer vary between UC and CSU, and between colleges. There is some standardization at CSU: at least 60 semester or 90 quarter transferable units or awarded a California Community College Associate in Arts for Transfer or Associate in Science for Transfer degree (AA-T or AS-T Degree) before applying transfer to the CSU. The UC schools are each unique and often don't intersect with the CSU. Also students can't take the upper level courses to transfer and depending on the college are lower level. **This will require policy change to permit x units of upper level STEM core courses be accepted by a UC/CSU. The alternative is the community college creates college-to-college transfer articulations as Foothill has done with CSU San Luis Obispo.**
7) Students are not able to take a STEM major core course in order to transfer. **This is a scheduling issue and financial. Each college can make this choice. Majority of Foothill STEM transfer classes are offered every quarter and in the summer. Less than 5% of students are not taken from waitlists.**

3. Innovations Prior to January 2014

In 2011-2013, Foothill College planned and tried out pilot projects for providing inclusive-academic-support services for STEM students. The aim was to improve the rate of students' success toward receiving a bachelor's degree by improving students' retention through the two-year community college program, and increasing their transfer into CSU and UC STEM majors. The main approaches of the Foothill strategies were to find ways to identify students' knowledge gaps early, to remediate shortfalls by early and easily available intervention, to support students in every way both academically and non-academically, and to provide financial and social support for students.

Pre-2014 innovations:

- Academic support services for STEM courses and pathways
  - A drop-in student tutoring center: the "PSME Center"
- Identification of student's knowledge deficiencies
  - Placement of students in courses, using the Accuplacer test
- Mentoring for student guidance
  - A 1-to-1 pairing program, "Pass the Torch," with a document to guide counseling
  - A full mentoring program, begun Fall 2013: see *Appendix B*
- Scholarships
  - Foothill College PSME division started a STEM scholarship program to provide financial and academic support for at-risk students so that they are better able to pursue their chosen STEM field of study. The scholarships enable students who ordinarily are required to work in jobs unrelated to their studies the opportunity to focus 100% of their attention on their academic pursuits. The project recruited and retained students in STEM fields of study to support their successful completion of required lower division STEM major coursework prior to transfer.
  - Eight students received STEM scholarships since its inception in Fall 2013. In addition to financial support, these students received mentoring, priority consideration for internships, academic services and community building activities.
- Promoting academic community and faculty involvement with students: In Fall 2013, PSME began a "STEM Meet and Greet": all entering calculus scholar students were invited to meet prior to the start of the quarter with their math instructors, as a resource for support. Instructors shared office hours, in addition to holding office hours in the STEM Success Center for drop-in tutoring throughout the quarter.
- Developed a new program in Biomedical Engineering, designed to accelerate students toward a BS degree, by closely articulating with core courses at a CSU.
  - The Foothill PSME dean and faculty worked with industry leaders and entrepreneurs and well as faculty from CSU, UC and Community Colleges. An advisory board was formed to receive valuable feedback and insure the growth of the program into specialties in need of workforce expansion. In this strong collaboration, a certificate in proficiency and 5 new courses in engineering were developed:
  - Introduction to Biomedical Engineering (ENGR83A)
  - Design and Manufacturing in the Biomedical Engineering Field (ENGR83B)
  - Introduction to Medical Device Regulations (ENGR83C)

- Introduction to Quality Assurance (ENGR83D)
- Introduction to Documentation (ENGR83E)

Impacts and Evidence: Prior to 1/2014

- Impact: Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program.

  Indicator to 1/2014: Target Math graduation: increase 5% to 14%, from projected baseline of 125 to 132

  After the pilot test year for the STEMWay project (2012-13), the key goal of increased student success was ahead of planned targets, even though unavoidable circumstances set back project development. The graduation rate of math students in the first full (2-year) student cohort increased by 26.7% over the previous year, which exceeded the target increase of 17.5% over baseline. The pilot test resulted in a major shift in the project's structure before fully launching in 2014: statewide changes in Learning Management System (LMS) policies, and difficulties in working with the planned commercial LMS, led to lower reliance on an LMS and greater concentration on tutoring, mentoring, and academic community development.

  Data from Foothill research showed positive association between students' success in the math sequence and participation in STEMWay Emporium services, with added value from increased participation in the Emporium. Data showed a moderate but steady correlation between amount of Emporium usage and success in Math-1: students who used Emporium 5 hours or more succeeded in Math-1 at about a +13% rate over those participating under 5 hours.

- Impact: Establish Emporium and increase Emporium usage.

  Indicator to 1/2014: Begin training of faculty and mentors for STEMWay.

  The STEMWay Emporium started with workshops and tutoring at the start of project, and grew to full service and visibility following the hiring of a full-time permanent director, Eric Reed, halfway through project Year-1 (the late start because of the project beginning well into the academic year). It is also called the STEM Success Center, and because of continuation from an earlier form it is also locally called PSEC for Physical Sciences and Engineering Center. Mentoring services were added, led by chemistry professor Sandha Rao and partly funded through a supplemental S-STEM grant from NSF. Usage of the key Emporium services, workshops and/or tutoring, among Math 1A students was 42% in Year1 (100 of 240), which was far above the target in the project proposal.

- Impact: Increase Emporium diagnostics and instruction and services.

  Indicator to 1/2014: Emporium readiness for 1 calculus course.

  Workshops were created to cover booster/scaffolding for calculus courses, and planned to be added for other math courses and for chemistry and biology courses. Readiness testing, diagnostics, and booster/scaffolding were handled in a distributed and hands-on approach, while assembling best materials for each purpose. (See "Lessons Learned" in Appendix B for specific successful strategies.)

4. Innovations Since January 2014

Foothill College advanced in 2014 with the first fully active year of the STEMWay program of inclusive-academic-support services and its first formative evaluation; the full start of the new program in Biomedical Engineering, which is tightly articulated with the CSU major and designed to give students leveraged ability to achieve a BS in the field; new and expanded scholarships, mentorships, and internships with particular focus on support and advantage for underrepresented students; new developments in faculty collaboration and growth of an active learning community; added resources and aids for students, including use of advanced tools like a 3D printer, and a speaker series by industry leaders; redesign of a core engineering course to improve chances of success for underrepresented students; and start of research to gain feedback on student progress beyond time at the local college, for improved feedback on course and program development.

Full implementation of STEM inclusive-academic-support services centered on Foothill's *STEMWay* project, following setup and pilot testing in 2013. Some of the innovations worked as well as or even better than planned: including an "early warning" system to identify students needing help; drop-in targeted tutoring workshops; and expanded services and course offerings. Some of the planned innovations needed modifications: e.g., reliance on computer-based instructional support programs. Some new innovations were added with strong results: department-wide and inter-departmental collaboration; and growth-oriented planning with faculty. An internal Foothill evaluation in summer 2014, and an independent external evaluation in fall 2014 both showed positive results from several of the recent innovations, and identified a few as particularly effective. The feedback for improvements is useful for the expanding of STEMWay throughout the STEM majors in the next few years.

Key Specific Innovations in 2014:

- Academic support services that closely parallel STEM courses and pathways.
  - Drop-in student tutoring center: PSME Center and STEMWay project.
    - Added workshops for targeted tutoring in all STEM subjects.
    - Began adding non-academic support workshops: resume writing, applications, writing reports
- STEMWay active early intervention strategies: Early identification of student's knowledge deficiencies, with an intensive intervention in remediating knowledge gaps.
  - Preliminary assessment: In first week of main entry Math course (MATH-1A), test for mastery skills comprehensive pre-requisite skills.
  - Led to using a new identification test as a predictor of success, adding in coverage for semantics, to aid cultural differences, under-represented groups.
- New Biomedical Engineering track and certificate program, tightly articulated with the CSU major and designed to accelerate students through a BS in the subject, started fully in Fall 2014.
  - The new five engineering courses and the Certificate in Proficiency program officially started Fall 2014. Two of the courses received one-to-one articulation with CSU SLO courses. The dean and faculty continue to build on the strong relationship with industry by meeting with industry leaders and entrepreneurs on a regular basis.

- Redesigned the core Engineering course (ENGR-10) to cover underrepresented groups.
  - New methods eliminate competition, and emphasize teamwork, design work.
- Scholarships increased, and academic community furthered.
  - In 2014, 13 new scholars were selected and 4 scholars are continuing from last year, for a total of 17 scholars.
  - The scholars are offered academic support. All but one of the scholars (11 of 12) took advantage of this resource during the 2013-2014 academic year.
  - In the Winter 2014 quarter, a lunchtime Pizza social was held on-campus for faculty mentors and student mentees to give everyone a chance to meet each other. Information was distributed on scholarship requirements and faculty and scholarship students were introduced to each other.
- Internships added.
  - The traditional research internships of Foothill College students at four-year research colleges and industry continued. In addition, Foothill College funded energy interns (part of engineering course) to work on campus to gather detailed building data and provide analysis. 25 students were funded for two quarters. Many of the interns transferred to four-year colleges.
  - The Biomedical program was very successful in identifying internships. The advisory board recommended internships at small biomedical companies, where students will receive broader experience. Internships were being developed at UC Irvine, Fogarty Institute for Innovation, Triple Ring, Lumenous, Gauss Surgical, and nVision. The Fogarty Institute for Innovation is one of our partner organizations (support letter in Appendix A).
  - The Biomedical program is expanding summer internships to include UCSF Neuro-science and QB3 (an incubator). 20-25 (underrepresented / women / veterans) Foothill and 10 Eastside Prep Charter School (100% underrepresented) students will participate (UCSF-SLI; see support letter in Appendix A). Students will select tracks of interest such as medical devices, computer science and biotechnology.
- Scholarships with mentoring.
  - The S-STEM scholarship program began, providing scholarships for 15-20 students.
  - Each S-STEM scholar recipient is each assigned a faculty advisor. A counseling specialist (Will Walker & team) is also assigned.
  - Students become involved by:
    - students referred by faculty
    - outreach into classes (academic + financial + psychological)
    - PSME Center Director (Eric Reed) for workshops
- Mentorship in STEMWay.
  - Students and faculty discuss and sign a mentoring contract that includes guidelines for mentoring and expectations of both the student and faculty mentor. Students and faculty were advised to meet at least 3 times (weeks 1-3, 4-7 and 8-11). Students and mentors 3 times each for the Winter and Spring 2014 quarters. Actual meeting numbers are probably higher, since some faculty mentors met with the students privately.

Quarter	STEM mentor/ mentee pairs actively participating	# of faculty filling out checklists	% of meetings reported online (of those faculty submitting checklists)
Fall 2013 (1 meeting)	12	9	100% (9/9 meetings)
Winter 2014 (3 meetings)	12	8	75% (18/24 meetings)
Spring 2014 (3 meetings)	9	5	80% (12/15 meetings)

- Active learning community
  - Initiated a Growth Mindset collaborational approach to encouraging learning in students.
    - Implanted a survey to measure Growth Mindset.
    - Studied intervention methods: a paper on how the brain grows; activity to write a letter to a friend to help grow; post-measures.
    - Shown to work on developmental Math; tested at Foothill College for core Math (Calculus). Did a double-blind experiment with Pre-Calculus and MATH-1A.
    - Led by faculty L. Silverman, Ben Stefonik. Working with Carnegie Institute, Stanford; Carol Dweck.
  - ”Belonging”: (L. Silverman & S. Parikh) from “STEM Day”, training of faculty, who then contact students, using email (guided, using templates). A STEM Web site centralizes and organizes the multi-collaborational work.
- Continual involvement by all STEM faculty members for collaborative improvement.
  - Started a STEM Web site. MATH-1A faculty meets weekly.
  - Inter-faculty collaboration is helped by the new Science Learning Institute (SLI) building with adjacent offices, and a discussion environment (different departments are in the same building; several conference rooms, and many central discussion areas).
  - Cross-department coordination with English, Business (Psychology faculty helping with Growth Mindset, "Belonging," getting data), Fine Arts (a recording studio for high-quality lectures, Corsara-like); Biological and Health Sciences (medical devices, STEM internships); Scholarship committee inter-departmental.
  - Published an Engineering Newsletter
  - Program review (by PSEC dean) requires faculty to work together for requests.
- Speaker series of industry leaders:
  - Leadership Lunch: STEM leaders in the Bay Area give inspirational talks, e.g. Elizabeth Blackburn
  - Frontiers in Science: researchers in weekly lunch
  - Also in 2014, in Engineering: talks by practicing engineers.
- Advanced tools and techniques used in courses: 3D Scanner/Printers

- PSME faculty involved in American Society for Engineering Education.
  - Began a new research study on understanding and improving STEM pathways through community colleges.
- Scientific management to enable comprehensive support with limited resources.
  - Foothill research began monitoring student success rates, for feedback on long-term results of innovative methods at Foothill.
  - Costs savings: metrics showed that a better completion rate through 2 years will increase 4-year bachelor's degree completion rates.
  - Elevating education at Foothill College to UC-level saves money on costs for a BS.

Impacts and Evidence: in 2014 (See Appendix C for details)

- Impact: Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program.

  Indicators to 1/2015: Target math graduation: increase 32% to 17.5%, from projected baseline of 128 to 172

  After the first project year (10/2012 - 9/2013), the key goal of increased student success was ahead of targets as stated in the project's proposal, even though unavoidable circumstances set back project development in its first year. The graduation rate of math students in the first full (2-year) student cohort increased by 26.7% over the previous year, which exceeded the target increase of 17.5% over baseline. Halfway (1-year) figures of the project's second math student cohort suggest similar gains toward graduation. The data also supports a correlation between STEMWay Emporium services and increases in graduation rates.

- Impact: Increase STEM Course Enrollment.

  Indicators to 1/2015: Target STEM course enrollment increase: 5%

  Enrollment in Foothill College's math program increased beyond targets in the project's first two years. Gateway course Math 1A enrollment in the baseline year 2011-12 was 645; in the project's first year 2012-13 this increased by 5.7% (682), and in the second year 2013-14 by another 18.2% (806), or 25.0% (161) over baseline. This far exceeds the goal of the proposal, and is even more remarkable in that total enrollment at the college went in the other direction, decreasing -8.2% in project Year-1 (15,500 to 14,228) and by another -6.2% in Year-2 (to 13,347), a decrease of -14% in two years, vs. the core math sequence increase of +25%. Other factors are involved and there are no explicit data on the direct effect of STEMWay on student enrollment in math, but the growing usage of the Emporium suggests a positive effect, and progress toward this goal has certainly been a strong success after two project years.

- Impact: Establish Emporium and increase Emporium usage.

  Indicator: Target emporium usage (% of key STEM course enrollment): 20%

  The STEMWay Emporium grew to full service of workshops and tutoring and visibility following the hiring of a full-time permanent director. Mentoring services were added, led by chemistry professor Sandha Rao and partly funded through a

supplemental S-STEM grant from NSF. Usage of the key Emporium services, workshops and/or tutoring, increased among Math 1A students from 42% in Year1 (100 of 240) to 64% in 2014 (189 of 296). These figures are far above the targets of the project plan. In 2014 the number of Foothill College students who used the Emporium heavily (over 12 hours) increased by 65%.

- Impact: Increase Emporium diagnostics and instruction and services.

  Indicator: Emporium readiness testing, booster/scaffolding for 3 calculus courses.

  STEMWay focused on using workshops, tutoring, and mentoring for students. Workshops were created to cover booster/scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses. Readiness testing, diagnostics, and booster/scaffolding were handled in a distributed and hands-on approach, while assembling best materials for each purpose.

  The project applied its approach in supplying complete out-of-the-classroom services, and focused instruction to fill knowledge gaps for students. It shifted its focus from heavy use of a custom-programmed LMS to intensive instruction in workshops and by tutors. Workshops have been created to cover booster / scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses.

  The active usage and apparent value for students seems due largely to the full-service approach of STEMWay, to the active and responsive Director of the Emporium/PSEC, and active faculty collaboration fostered by the approach adopted by project PI Silverman of "Growth Mindset." The latter is an approach of persistence in learning, promoted by the Carnegie Foundation and brought to STEMWay and other Foothill College staff. Mentoring has increased, with a schedule of instructors based on demand managed by the Emporium Director, and covering several subjects in addition to math.

  Some methods that contributed to the effectiveness of the STEMWay Emporium in aiding STEM students (see Appendix C for details):

  - Workshops covering math, chemistry, and biology courses.
  - "Early alert" program.
  - A "Foundations lab" to support students in pre-college level math classes.
  - "Test corrections" mastery instruction system.
  - Acceleration program: a summer bridge program to help students start college with credit for a higher math course, and so have a greater chance to graduate.
  - Worksheets maintained for students covering course subjects.
  - Peer-tutoring: Started with Math; expanded to cover new subjects.
  - Integrated Emporium activities into Math 1A classes.
  - Feedback to and from instructors, to improve teaching and Emporium offerings.
  - Practice sessions with faculty on best practices in providing support.
  - Coordinating with the "Teaching and Learning Center" for integrated and consistent services.

    - Diversification in professionals: Hired two minority instructors in subjects that previously had none.
    - Internal Advisory Committee (IAC): Improved the test corrections process, obtained resources from instructors for workshops, and redesigned a workshop based on instructors' ideas.
- Impact: Provide STEMWay Internships.

  Indicator: Begin to offer STEMWay internships.

  Internship programs were made available at Foothill College in 2013-14, including research internships at Stanford University, University of California Santa Cruz Advanced Systems Laboratory, San Jose State University, and San Jose Technical Museum. An internship building block was installed in the math LMS in Fall 2013 (and will also be provided in the interim Etudes LMS in Fall 2014), along with Foothill College's own internship department.
- Impact: New Biomedical Engineering program (articulated with CSU) offered

  Indicator: Begin STEMWay internships.

  The newly approved and articulated engineering course in Introduction Biomedical Engineering was a complete success. The initial enrollment was 30 out of 35 students. The class received a number of guest speakers from the industry and from the federal government.

Lessons Learned (see Appendix C for details):

- Student subgroups differ in incoming academic work habits, but all can be reached and improved at similar growth rates.
- Usage of the central academic aid center can and was increased significantly by several specific steps:
    - Expanded availability: from initially 37 open hours/week to 59.5 hours/week.
    - Improved Emporium facilities:
    - Expanded Emporium communication and outreach:
        - Open house each quarter; published schedule; public activities.
        - In-class visits, financial aid workshops, flyers.
        - Specialized workshops for STEM scholarship applications.
        - Financial aid informational workshops.
- A central students' academic aid center (Emporium) can improve students' success by continually improving diagnostics, tutoring, counseling, and community services, without relying on programmed systems and materials (LMS).

5. Innovations Planned After January 2015

In 2015-2020, Foothill College will be refining and extending all of the innovations listed in 2014, and those listed pre-2014 also. All have shown some success, some of them through metrics and formal evaluation, and some through feedback of participants. The one major planned innovation that did not work as well as planned was the use of a LMS (learning management system) as part of STEMWay services, and that approach will be substituted by Foothill's involvement in California's Online Education Initiative (OEI) initiative.

In particular, continued improvements in STEM education at Foothill College will continue and grow with the new Science Learning Institute (SLI), which recently opened as a new campus at the college. The innovations under the STEMWay project will continue at least through AY 2016-17; if those continue to be successful, they will then be instituted in non-STEM subject areas at Foothill, and disseminated for application nationwide.

The very successful open-door tutoring and workshops of the PSME Center will continue and will add further space to accommodate the large number of students who use it. Workshops are beginning to include non-STEM subjects and soft skills, and more of those will be added. The successful methods in mentoring, "early warning" instructional intervention, addition of faculty from underrepresented groups, and mentored scholarships will continue and expand. New strategies and practices that will begin in 2015 include the following:

Planned Innovations 2015-2020:

- Add a "Growth Mindset" approach to collaborative instruction in STEMWay.
- Add new mastery-based diagnostic tests for STEMWay courses for better placement, early diagnosis of needs, and identification of need areas during courses.
    - Fine-tune new test based on its success as a predictor.
    - Add the identification test for Math 1B and 1C, then Chemistry and Physics.
- Detail and tighten a "linked learning pathway" for the new Biomedical Engineering program, from high school through Bachelor of Science degrees.
    - Grow and expand the Biomedical Engineering program into an AS degree.
    - Increase course offerings from one time to 2-3 times a year.
- Improve feedback and formative program improvement by closer monitoring of students' progress and success beyond the community college.
- Add in non-academic support workshops: resume writing, applications, writing reports.
- Mentoring for progressive student guidance.
    - Start study groups for peer mentoring
    - Set up peer support: recommending and advising, directed by Will Walker, with one coordinating student per class
    - Academic community communication by “student advertising”
    - Extend guided counseling to 1-to-many per class.
- Active learning community
    - Professional development: train faculty in all STEM subjects
    - Measure for retention + success. Include feedback to students.

- Extend involvement by all STEM faculty members for collaborative improvement.
    - Cross-campus staff development (Ben Stefonik)
- Begin an automated, STEM-wide coordinated "Early Alert", for scientific management of resources.
- Research project (S. Parikh): Understanding and improving STEM pathways through community college
- Evaluate redesign of ENGR-10 to aid learning for underrepresented students, and apply to additional courses
    - Method: Eliminate competition; emphasize teamwork and design work.
- Extend the full set of STEM inclusive-academic-support services throughout STEM major programs, and following that throughout the college.
    - Expand approach of elevating education to UC-level, for cost savings on average cost of achieving a four-year bachelor's degree.

Impacts and Evidence: Planned 2015-2020
Specific Goals, with Indicators and Benchmarks:

- Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program. *Indicators:*
  2015: Target math graduation: increase 69% to 22.5%, from baseline of 135 to 237
  2016: Target math graduation: increase 88% to 25%, from baseline of 141 to 288
  2017: Target math graduation: increase 95% to 26%, from baseline of 149 to 331
- Increase STEM course enrollment. *Indicators:*
  2015: Target STEM course enrollment increase: 7%
  2016: Target STEM course enrollment increase: 9%
  2017: Target STEM course enrollment increase: 10.5%
- Establish Emporium and increase Emporium usage. *Indicators:*
  2015: Target emporium usage: 30%
  2016: Target emporium usage: 40%
  2017: Target emporium usage: 50%
- Increase Emporium diagnostics and instruction and services. *Benchmarks:*
  2015: Emporium readiness testing, scaffolding for chemistry courses.
  2016: Emporium readiness testing, scaffolding for physics courses.
  2017: Emporium readiness testing, scaffolding for computer science courses.
- Provide STEMWay Internships. *Benchmarks:*
  2015: Increase STEMWay internships.
- Disseminate project outcomes and consequences. *Benchmarks:*
  2015: Dissemination of mid-project outcomes.
  2017: Dissemination of project outcomes; report on success of STEMWay project.

6. Impact on Costs of Bachelor's Degree Award

Foothill College's innovative practices are increasing the numbers of students who are able to transfer into 4-year STEM bachelor's degree programs at California universities, while also decreasing the average total time needed to earn the Bachelor of Science. Foothill's increased offerings of STEM courses that directly articulate to UC and CSU STEM majors, and the increased preparedness of Foothill STEM students, significantly improve the likelihood that students will receive their BS degrees in four years instead of six. In the coming years, Foothill College will be extending this model to non-STEM majors as well as to other community and state colleges.

The average cost to award a STEM bachelor's degree is reduced in at least two ways:

1. Foothill College STEM students typically achieve a bachelor's degree in 4 years. The increase in the number of STEM transfer students provides a total financial advantage. To gauge the cost savings, consider the total costs for graduating students at the CSU and UC campuses that receive the most transfer students from Foothill College: San Jose State University (SJSU) and UC Davis (UCD; UC San Diego also receives a large number of Foothill transfers). 67% of STEM transfers from Foothill College to a CSU graduate in 4 years, and 79% of Foothill transfers into a UC graduate in 4 years. Some of the following analysis uses data from *http://collegemeasures.org/4-year_colleges/state/ca/compare-colleges/cost-per-student/*:

Cost (reimbursement) Foothill (2 years):	2 x $4,660 = $9,320
Cost SJSU (2 years):	2 x $12,997 = $25, 994
Cost transfer degree, Foothill (2 years) & SJSU (2 years):	$9,320 + $25,994 = $35,314
Cost SJSU (4 years):	4 x $12,997 = $51,988

Cost Savings

SJSU (4 years) – (Foothill (2 years) & SJSU (2 years)):
$51,988 - $35,314 = $16,674

Approximately 67% of STEM students from Foothill College who graduate from a CSU in a total of 4 years. The average cost savings per student is $16,674 compared to students who spend all 4 years at the SJSU. The total cost saving is

In the last 4 years, 80 students transferred to CSUs and 53 of those students will graduate in total of 4 years. This total cost saving for this group of students is 53 students x $16,674 = **$883,722.**

For Foothill College students who transfer into a UC, the cost savings is considerably higher, $52,466 per student:

Cost UC Davis (2 years):	2 x $30,893 = $61,786
Cost for transfer degree: Foothill (2 years) + UCD (2 years)	$9,320 + $61,786 = $71,106

Cost for 4 years at UCD: 4 x $30,893 = $123,572

Cost Savings

UCD (4 years) – (Foothill (2 years) & UCD (2 years)):

$123,572 - $71,106 = $52,466

In the last 4 years, 235 students transferred to UCs and 185 of those students will graduate in total of 4 years. This total cost saving for this group of students is 185 students x $52,466 = **$9,706,210.**

2. Foothill College partners with CSU San Luis Obispo (Cal Poly) to provide a degree program in Biomedical Engineering, in which students take Biomedical courses at Foothill prior to transfer. The student success rate for Cal Poly Biomedical students is only 62.9% after 5 years. By being able to take both core and advanced major courses at Foothill in the first 2 years, we expect a higher success rate within 4 years instead of 5, and for those students there is a significant savings to the state:

Cost (reimbursement) for 2 years at Foothill:	2 x $4,660 = $9,320
Cost for 2 years at Cal Poly:	2 x $14,939 = $29,878
Cost for transfer degree, FH + Cal Poly: Foothill (2 yr) + Cal Poly (2 yr)	$9,320 + $29,878 = $39, 198
Cost for 5 years at Cal Poly:	5 x $14,939 = $74,695
Cost savings, FHC transfer vs 5-yr at SLO:	$74,695 - $39, 198 = $35,497

For these students, the savings to the state is $35,497 per student, or 48%

Foothill College is now starting to track the success rate of transfer students into 4-year bachelor's degree programs. Foothill will be monitoring the completion rates and cost savings for STEM students.

7. Risks and Tradeoffs

Most of the risks in Foothill College's recent innovations were taken in 2011-14, with the planning, design, and implementation of broad and highly innovative strategic practices. Peter Murray, Executive Dean, while at Foothill directly managed $4M in grants, prior to that owned two software companies and managed large programs for an aerospace company. New initiatives were based on research and collaboration. Because of that, considerable time, resources, and effort were put into developing fully inclusive academic support services and putting them into a detailed production and expansion plan with annual evaluation metrics.

Many initiatives are started with a pilot program. This includes programs such as MathMyWay (Basic Skills Math program with 80% success rate), STATway (coordinated with Carnegie Foundation for the Advancement in Teaching for college transferable math), STEMway (STEM course scaffolding and support system), PSME virtualization program and Biomedical course sequence. For example for STEMway, it had a rough pilot testing year in 2013, but then the full program in 2014 had results strongly passing target goals, especially in the project's central service: the PSME Center. In the year-end evaluation, it was found that use of the PSME Center "has been succeeding far beyond target goals, to the point of straining the college's ability to serve the continually growing amount of student interest."

The STEMWay plan proposed that the planned services could aid students so well that not only would they achieve greater academic success, but the results could lead to a broader interest in Foothill College's STEM program, and increased student enrollments. The total number of student successes (AS degrees and transfers into 4-year BS programs) could thereby increase at Foothill College doubly: both by improved rate of graduates and transfers, and by increased influx of registering students. So far, after just one pilot-test year and one fully operational year, all three predictions are being met and surpassed: the PSME Center is popular with students beyond expectations; students' academic success rates are improving in the field targeted by STEMWay (Math); and registrations in Foothill STEM courses are increasing, even while registrations in the rest of the college have been decreasing.

The main risk in the continuation and expansion of the STEMWay inclusive academic services is the ability of the college to accommodate the increases of students coming into the STEM programs and making use of STEMWay services. From another risk that was taken previously and has now worked out fortuitously, a new complex was built at Foothill College for STEM studies, the Physical Sciences and Engineering Center (50,000 ft^2 of state-of-the-art labs and classrooms).

Another general mitigation factor is partnering with other colleges such as San Jose State Univ., UC San Francisco, UC Santa Cruz, Stanford Univ., Gates Foundation, Carnegie Foundation, and Bay Area Community College Consortium. A further mitigation is having regular program reviews by internal and external "Board Members." This includes people such as Bruce Alberts (UCSF, Editor of *Science* Magazine, former President National Academy of Science), Jerry Cain (Stanford CS), Joseph Goodman (x-Dean Stanford Engineering), William Rutter (Founder of Synergenics and Chiron), William Coleman III (Founder of BEA systems), William Spenser (Chairman Emeritus of the International SEMATECH Board), Richard Swanson (Founder of Sunpower), Marc Tarpenning (Founder of Tesla Motors) and many from major corporations and educational institutes.

One current risk is not having enough scholarships to meet students' demand. To mitigate: If there is zero charge for tuition (i.e., if CC tuition is approved for "no cost", and Foothill tuition/fees is $1,500), the impact is to reduce scholarships from $4,200 to $2,700, and so the recipient can be a fulltime student and not have to work part-time, and the college can reallocate scholarships among additional scholars. If there is not that flexibility in tuition charges, then the college will seek additional funding: other financial alternatives such as PELL grants. In 2013-14, PELL Grants were awarded to 1,628 Foothill Students. Also 144 students who are veterans were provided grants.

Another risk is not being able to hire enough faculty to perform the innovative projects. Foothill College currently has excellent STEM Fulltime Faculty, and also a pool of Adjunct Faculty, many with a Ph.D. and having industry experience. Many of Foothill's initiatives have used a combination of Fulltime and Adjuncts. Adjuncts often have more time to provide than Fulltime who have other campus activities. A mitigation is often to recruit new Adjuncts with the required backgrounds.

Another risk is the lack of classroom/lab space for growth. There are two possible mitigations: one is to move classes to Foothill's new satellite 50,000 ft^2 campus in Sunnyvale, CA. A second is to continue to develop high quality (e.g., Coursera or Udacity) online course material for non-lab sciences. For computer science courses, students using PSME's virtual environment can do networking, operating system and data management labs from anywhere.

External Risks are:

1) A lack of courses at CSU (mainly) and UC schools delay transfer students' graduation.
   Mitigation: Have STEM students take more core courses at the community college so that they are less impacted by lower-level high-demand/attrition classes after transfer. Foothill's Biomedical program with Cal Poly SLO is one example of creating a coordinated sequence.
2) UC (primarily) and CSU universities change articulation agreements.
   Mitigation: Foothill's Articulation Officer is one of the best and works closely with the UCOP and other groups as well as each individual college. Resources need to be allocated to work with each UC and CSU to address changes and new courses. The CSU Transfer Degrees identify the core courses for transfer in a major, which is good. Foothill's Biomedical program with Cal Poly SLO is an excellent example of close coordination and cooperation.
3) UC & CSU limit number of transfers.
   Mitigation: Our Cal Poly Biomedical pathway can be further expanded with additional unidentified funds to expand their labs. They could accommodate twice as many transfers. The advantages to other colleges are that (a) it will ensure that students apply to multiple colleges for transfer, and (b) our student success story will be marketed to the UC and CSU schools.

8. Sustainability — Strengths and Assets

The Foothill STEM programs have continued to expand as well as address new challenges and opportunities. Foothill College has always had a culture of innovation as well as very collegial in developing new programs. Faculty continue to work with the Carnegie Foundation for the Advancement of Teaching. They are currently coordinating with Sheri Sheppard, Stanford Burton J and Deedee McMurtry University Fellow in Undergraduate Education and Professor of Mechanical Engineering on STEM teaching collaboration. Faculty also regularly present at major conferences.

Section 10 has the very affirmative commitment that the Foothill College President made at the 2nd College Opportunity Day of Action on Dec. 4, 2014 in Washington, D.C., at the White House, hosted by President Obama.

Foothill has developed partnerships with local four-year institutions and companies to provide collaborative studies, undergraduate research and internships, including Stanford University, California State University at San Jose, Cal Poly San Luis Obispo, University of California Santa Cruz, University of California Irvine, University California San Francisco, NASA AMES, Cisco, Microsoft, Triple Ring, Carnegie Institute, and Fogarty Institute for Innovation.

Cal Poly San Luis Obispo, UC San Francisco and Fogarty Institute for Innovation are members of this application. Cal Poly and Foothill College have been working together for several years on better transfer process and new course articulation. As part of our Biomedical Engineering program, Foothill students will visit Cal Poly and some of their students and a professor will visit Foothill. There are several areas for tighter coupling: (a) students from both campuses working on common projects, (b) students from both campus participating in the same internships, and (c) Foothill expanding the same process used for Biomedical articulation into Computer Science, Computer Engineering, Cybersecurity and Big Data majors.

UCSF and Fogarty Institute both support the internship program and also provide speakers and advisory board members. UCSF, Elizabeth Blackburn (Nobel Laureate) will be a speaker with Foothill STEM students in spring quarter. Al Chin from Fogarty Institute presented multiple different devices he developed and patented showing all of the design steps and the thought process. Both partners have incubator programs where Foothill students can be exposed to entrepreneurs as well as engineers and scientists. A Fogarty start-up uses some of the lab equipment available at Foothill. We anticipate the UCSF summer program to grow year over year as well as supporting Foothill's anticipated Bioinformatics program.

An area where Foothill leads all other Community and a number of 4-year Colleges is in online course development and delivery. This includes the $16.9M Grant for Statewide Online Learning Portal won by Foothill – De Anza District.

An example of Sustainability is the PSME Center

The PSME Center at Foothill College started as a one room "Math Center" staffed by hourly, classified tutors. As the center was staffed primarily with retired engineers, chemists and physicists, the center grew to support students in all of these subjects. By the 2011-12 academic year, the center was used by about 900 students each quarter, for a total of over 27,000 hours during the year. By 2012, the center has grown to 5 classrooms. From this point

forward, all tutors are required to meet "minimum qualifications" in the field they are serving. Instructors are hired to support biology classes.

Because of the high increase in usage as well as the introduction of new functionality, Foothill hired a full-time, interim director for the center and has initiated a search for a permanent tenure-track faculty director. The Center also is starting to offer workshops for calculus students. While voluntary, the workshops are similar to discussion sections or recitations at a university.

While the number of students receiving support remained steady, the hours served in the Center have increased to over 30,000. Additionally, about 200 students attended the calculus workshops for a total of 3,000 hours. Overall, traffic in the center increased by about 22%.

PSME Center Development, 2014:

With a permanent director in place, the PSME Center began a push to "market" the center to students who need it. The director visited most classes in math, chemistry, physics, biology, and computer science to describe the center's services. Workshops expanded to support students in all math classes, and many other STEM classes.

The Center added one more classroom and hosted enrichment activities such as a professional speaker series and financial aid workshops; even a Jenga competition as stress-relief before finals. The Center offered one Saturday review session in the winter and spring quarters which was attended by over 200 students, as well as several classroom instructors.

While the courses with the lowest success rates were at the pre-calculus level and below, at this point the students in the Center were primarily in calculus and above, as well as higher level chemistry and physics classes. In coordination with the Basic Skills committee, the Center made an active effort to attract the lower level students.

At the beginning of fall 2014, Foothill hired a full-time early alert coordinator to identify and counsel students who are at risk of failing or dropping out of STEM courses. In the winter a part-time counselor was housed in the PSME center and dedicated to STEM students. These efforts have already paid off, attracting more students who can truly benefit from the services of the center.

With the success of the Saturday review sessions, the center was now open every Saturday. This was well received by students, with 100 – 200 students attending each week. The Center is now open over 80 hours per week, and looks to expand further.

We have pushed to broaden the diversity of staff in the center by recruiting through professional organizations and diversity groups on local university campuses. In 2013, 100% of the staff was White or Asian. Today approximately 15% are Hispanic, African American or Indian.

The main PSME center also continues to grow. In fall 2014, the center hosted over 2000 unique students, and usage in terms of hours increased by about 46%.

9. Sustainability — Strategies

Engaging stakeholders (such as students, faculty, other education agencies or institutions, community members, and business leaders) is very important and Foothill has focused on it for STEM education. We have relationships with multiple Rotary groups and Foundations, as shown online at *http://foothill.edu/sli/advisoryBoard.html.* This also shows that Foothill has extensive connections with industry and educational leaders.

Foothill College holds regular meetings with the different program advisory groups. We also request our current advisors to solicit new members as well as make connections with others in industry and other educational institutions. The Foothill College President attends regular meetings in Washington, D.C., for National Academy of Science as well as special Department of Education committees, including a recent one at the White House.

Foothill actively recruits from local high schools as well as having Opening Day STEM events to encourage students to consider STEM majors. Financial Aid staff attend the opening day as well as regular events in the PSME Center on FAFSA and scholarship preparation. Foothill offers a nanotechnology course at two local high schools.

Foothill College holds yearly STEM Summer Camps, which is a program for freshmen, sophomores, juniors or seniors. This camp focuses on strengthening and expanding student's scientific knowledge through hands-on experimentation. Last year, Foothill College welcomed several hundred students and next year it will be doubling the number of available sessions and therefore also the number of participants. This camp also provides an opportunity for Foothill faculty from various departments as well as high school teachers to work together on one common goal of exciting student's interest in STEM.

For example, to engage industry into Biomedical innovative practices at Foothill College, faculty and the Dean of Physical Science, Engineering and Math arranged meetings with Silicon Valley entrepreneurs and industry leaders in innovation. The Biomedical advisory board was formed to continue receiving valuable feedback and insure the growth of the program into specialties that are in need of workforce expansion. One of the first in-person meetings was with Dr. Thomas Fogarty, the nationally renowned inventor of the balloon catheter. Just a few months ago, Dr. Thomas Fogarty was awarded the Presidential National Medal of Technology and Innovation, which is the country's highest honor for achievement and leadership in advancing the fields of science and technology. In the meeting, Dr. Thomas Fogarty supported the efforts in developing programs at Foothill College. Additionally, Dr. Michelle Khine, serial entrepreneur and UC Irvine associate professor of biomedical engineering, chemical engineering and materials science visited Foothill College in March of 2014. She gave an exciting and informative open to public lecture in which she discussed the growing need to cultivate "home-grown" STEM student innovators. She encouraged students to pursue STEM educational and entrepreneurial opportunities.

Another strategy that Foothill practices is taking its students on industry tours. Recently, Foothill faculty and engineering students visited medical device development and manufacturing facility, Phoenix DeVentures Inc. in Morgan Hill, CA. The company provides a range of services for designing, developing and manufacturing of medical devices. This tour made the students more excited about their future career opportunities.

10. Sustainability

Dr. Judy Miner, President of Foothill College attended the 2nd College Opportunity Day of Action on Dec. 4, 2014 in Washington, D.C., at the White House. Hosted by President Obama, this event supports the President's commitment to partner with colleges and universities, business leaders, and nonprofits to support students across the country to help our nation reach its goal of leading the world in college attainment. Below is Foothill's commitment as recorded in the minutes to sustainability of the continued innovation and support to existing programs.

Goal: Foothill College is committed to expanding its STEM student population by 5% per year and to increase its graduation rate by 95% above current rates within five years.

Action Plan: To meet this commitment, Foothill will continue to expand on its STEM programs, consistent with recent research on STEM student success and retention: academic support services that closely parallel STEM courses and pathways; analytical management to enable comprehensive support with limited resources; comprehensive mentoring services for progressive student success within an active learning community; stimulation of student learning via flipped classrooms, actively learning and growth mindset; and undergraduate research and internships. This will include:

- Recruiting more students into STEM majors by using faculty as STEM role models, especially for underrepresented students. These include Puente Program (helps Latino students transfer to four-year institutions), Pass the Torch (pairs high achieving students with minority students in study teams), and an active Student Outreach and Retention Office.
- Giving students academic support with a dedicated "STEM emporium" space: STEM programs will apply a scaffolding strategy that includes readiness testing for core STEM courses, along with booster modules to get students' skills up to course requisite skill level. A STEM emporium is in a centralized physical location and has a mechanism to coordinate student assessments, booster/scaffolding instruction, and mentoring. The STEM emporium works in close collaboration with each student's instructor to ensure that remedial work has been completed and that the student has gained the skills to join and succeed with the other class participants.
- Expanding opportunities for STEM research and internships through partnerships: Foothill has developed partnerships with local four-year institutions and companies to provide collaborative studies, undergraduate research and internships, including Stanford University, California State University at San Jose, CalPoly San Luis Obispo, University of California Santa Cruz, University of California Irvine, NASA AMES, Cisco, Microsoft, Triple Ring, and Fogarty Institute for Innovation.
- Supporting the ability of STEM teachers to continue to improve their instructional practices: Foothill's Science Learning Institute (SLI) provides an innovative model based on educational research and best practices for the successful teaching and learning of science, technology, engineering and mathematics at all levels. This includes STEM summer camps, scholarships, summer Math Bridge, online course creation, using the campus as a living laboratory, and cutting edge curriculum in biomedical devices, 3D printing, green chemistry, Big Data, quantum computing, and energy.

11. Evaluation — Method

The primary goal for Foothill College STEM education is to increase the number of STEM student graduations substantially: associate transfer degrees and transfers to Bachelor of Science STEM programs. The 5-year goal is to increase Foothill College's college-math graduation rate by 95%, to 26% of STEM FTES in 2019. The general approach is to improve the potential for success of all STEM students – especially for midrange (C and low-B) students – by continuous interventions, personal mentoring, and centralized tracking; thereby increasing student retention and transfers into 4-year STEM programs.

The innovations and advanced practices that are part of the STEMWay project (see Section 4) are under a defined evaluation plan, in effect at least through Sept. 2017. See the STEMWay Evaluation Plan in Appendix H. For the main Foothill STEM education strategic goals, following are the approaches to evaluate their effectiveness in 2015-2020:

1. Innovative academic support services that are tightly integrated with STEM courses and pathways. **Metric: Increase student success in PSME from 65% to 70% (approx. 1,000 student grades); test for increase of at least 1%/year 2015-2020.**
2. Scholarships and mentoring for progressive student guidance and an active learning community. **Metric: Continual increase in number of transfers by unrepresented and low-income students.**
3. New (online and hybrid) STEM courses created to articulate with UC and CSU core STEM major courses. **Metrics: Increase UC 4-year BS rate from 60% to 65% in 4 years; CSU BS rate from 58% to 65% in 4 years. Reduce the number of core STEM courses that students are required to take after transfer into 4-year BS program.**
4. Full complement of STEM courses all year around that provide opportunities for students from various universities and colleges to catch up with major requirements, stay on track and get ahead of their schedules; **Metric: Increase transfer rate by at least 1%/year.**
5. Internships and special programs to encourage students to pursue and persist in STEM majors, with priority focus on underrepresented groups**. Metric: Increase in student retention in STEM (Foothill research is still creating a baseline).**
6. Saving in the cost of obtaining degrees through institutional research that allows close monitoring of student progress. **Metric: Sustain, expand, and extend services with constant budget.**

Foothill PSEC will develop a formative evaluation plan to assess the ongoing success of these strategic goals, while maximizing the opportunity for success by continuous feedback and recommendations to faculty and administrators, who can then make adjustments for re-evaluation**. Currently, #1 and #2 above are being tracked**. **#3 is currently tracked for the BioMedical sequence and same methodology will be used for new courses. #4 will be a new evaluation based on interviews as well as tracking student persistence. #6 will be holistically evaluated based on business models and ROI**. Foothill has already created baseline measures for STEM success, and a quantitative progress plan for analysis of expectations versus results. BS success rates are tied to UC/CSU feedback. Evaluation methods for expected pathways, progress rates, and longitudinal sequence success are currently being developed by Foothill Internal Research.

12. Evaluation — Target Outcomes

Target metrics for the innovations and strategies that are part of the STEMWay project are shown in the STEMWay Evaluation Plan (through Sept. 2017) in Appendix H. The metrics monitor the progress of development of STEMWay services, the usage of STEMWay services by students, and the level of student success rates in the core STEM subject of Math.

Foothill has a fulltime Institutional Researcher, Elaine Kuo Ph.D., who provides independent evaluations and reports. She generates regular reports that track STEM student success and persistence, in particular longitudinal analysis in a sequence. The analysis is standard for the CC Chancelor's Office, but how STEM is defined needs to be shared. She also reports on the transfer rates to UC and CSU. See Appendix H for supporting data.

		ACADEMIC YEAR					
	OBJECTIVE	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
#1	Innovative academic support	65%	66%	67%	68%	69%	70%
#2	Scholarships and mentoring	14	16	18	20	22	24
#3	New STEM courses	UC : 60% CSU: 58%	61% 60%	62% 62%	63% 64%	65% 65%	66% 66%
#4	Full compliment of courses	UC : 60% CSU: 58%	61% 60%	62% 62%	63% 64%	65% 65%	66% 66%
#5	Internships and special programs	40	40	45	45	50	50
#6	Cost savings						

Below are the target outcomes for each academic year through 2019-20 for the measures identified in Item 11, where 2014-15 is the baseline number. These indicate targets for the combination of increased success rates by students in STEM courses at Foothill, plus expected 5% per year STEM enrollment growth with Foothill College opening a new Silicon Valley campus in 2016, creation of new course major sequences transfer in Biomedical (completed), and plans for Bioinformatics, Additive Manufacturing, Mobile Computing and Big Data.

Baseline data for STEM BS degree awards for 2009-2010 is shown below. The yellow is the four-year graduation year from completing key STEM courses at Foothill. Based upon the trend, the numbers are consistent with the projected numbers above. CC students often do not identify a major, but are tagged once they complete a traditional STEM transfer course. This data is from the National Student Clearinghouse (NSC) and data has a 2-year time lag. NSC reported about 18% of the 3,445 had their IDs blocked so that no tracking could be done. Foothill's completion rates are higher than the UC & CSU freshman rates.

		Graduation Year															
		2008-09		2009-10		2010-11		2011-12		2012-13		2013-14		2014-15		Total	
System	Initial STEM Enr	Students	Percent	Students	Percent	Students	Percent	Students	Percent	Students	Percent	Students	Percent	Students	Percent	Students	Percent
CSU	2007-08	2	3%	4	9%	18	35%	14	55%	19	83%	11	99%	1	100%	69	100%
CSU	2008-09	2	3%	3	8%	8	21%	23	57%	14	79%	12	98%	2	100%	64	100%
CSU	2009-10	2	3%	1	4%	3	8%	16	30%	20	58%	29	98%	1	100%	72	100%
CSU	2010-11 (Incomplete)					6	13%	7	28%	13	55%	19	Inc	3	Inc	48	100%
CSU	2011-12 (Incomplete)											12	Inc			12	100%
UC	2007-08	3	2%	27	18%	66	57%	42	82%	20	94%	8	99%	3	100%	169	100%
UC	2008-09	6	5%	2	7%	26	28%	47	67%	29	91%	11	100%			121	100%
UC	2009-10					10	7%	22	23%	51	60%	49	96%	3	98%	135	100%
UC	2010-11 (Incomplete)							3	2%	33	27%	71	81%	10	Inc	117	100%
UC	2011-12 (Incomplete)											24	Inc	3	Inc	27	100%

KEY: Years after first STEM:	
	3 years
	4 years
	5 years

note: There is a typical one to two year delay by CSU and UC into the National Student Clearinghouse database.

The success rate projections are based on the core math courses required for STEM students: Math 1A thru Math 1D (Single Variable and Multiple Variable Calculus). A number of the innovations noted in the prior sections are the reason for the successful improvement as well as reduction in the number of withdrawals. The increase in number of students and success rates is consistent with the above projections. Similar enrollment and success improvements are expected in other STEM courses.

Success Rates by Course (multiple years)

			Success		NonSuccess		Withdrew		Total	
			Grades	Percent	Grades	Percent	Grades	Percent	Grades	Percent
MATH	F001A	2011-2012	467	52%	255	28%	181	20%	903	100%
		2012-2013	509	57%	247	28%	134	15%	890	100%
		2013-2014	620	58%	273	26%	168	16%	1061	100%
	F001B	2011-2012	400	55%	183	25%	141	19%	724	100%
		2012-2013	379	59%	167	26%	94	15%	640	100%
		2013-2014	485	58%	228	27%	124	15%	837	100%
	F001C	2011-2012	219	61%	79	22%	61	17%	359	100%
		2012-2013	255	63%	87	22%	60	15%	402	100%
		2013-2014	288	66%	95	22%	51	12%	434	100%
	F001D	2011-2012	99	55%	55	30%	27	15%	181	100%
		2012-2013	146	69%	34	16%	33	15%	213	100%
		2013-2014	145	66%	51	23%	23	11%	219	100%

Foothill's two largest percentage growth populations are Latino and "Decline to State". Anecdotally as Dean of PSME, "Decline to State" are mostly underrepresented students. The growth is based on Foothill's growth projections and Santa Clara county demographics. Student academic support, scholarships and internships have the most impact on their ability to transfer.

As noted in prior sections, there is no one innovation that will produce significant change. Foothill faculty have presented a number of the innovations at the League for Innovation, Carnegie Foundation for the Advancement for Education, American Society for Engineering Education, and Stanford School of Engineering Education. (Foothill College does not have the financial resources to have a Bay Area or California-wide conference to identify the innovations and how to implement them.) The new STEM courses once articulated will be visible on Assist.org and all course outlines will be made available.

Transfers to Four-Year Institutions by Ethnicity among STEM Enrollment Cohort

	2007F-2014Sp		2018F-2019Sp	
Ethnicity	All Students	Percent	All Students	Percent
African American	19	2%	31	2%
Asian	539	52%	674	45%
Decline to State	106	10%	230	15%
Filipino	29	3%	35	2%
Latino/a	55	5%	165	11%
Native American	7	1%	7	0%
Pacific Islander	4	0%	4	0%
White	281	27%	365	24%

Appendices Permitted in DOF Application:

App	Sec		Sec Max	App Max	**Pages.**	What
A		Cover page: List of Participants	1	—		support letters from CEOs of each entity indicating for the application
		Abstract				
	1	Context and Goals	1			
	2	Student Population Factors	2			
B	3	Innovations Pre-2014	2	10	**8**	Appendix B - DOF Sec 3 - Pre-2014.doc
C	4	Innovations In 2014	6	15	**6** **9**	Appendix C - DOF Sec 4 - 2014.doc Evaluator Report STEMWay Y2.pdf
D	5	Innovations Post-2014	2	10	**—**	additional supporting materials
E	6	Impact on Costs of BS	1	5	**—**	additional supporting materials
	7	Risks and Tradeoffs	2			
F	8	Sustainability — Assets	2	10	**2** **2** **1** **1** **3-9**	PSME Center.doc Biomedical Program 2.docx BME Courses - figure.doc STEMWay Summary .doc STEMWay Description.doc
G	9	Sustainability — Strategies	1	10	**9**	FHC Data
	10	Sustainability — Use of Funds	1			
	11	Evaluation — Method	1			
H	12	Evaluation — Target Outcomes	2	10	**2-4**	STEMWay Evaluation Plan

FOOTHILL COLLEGE
OFFICE OF THE PRESIDENT

JUDY C. MINER

December 1, 2014

Executive Dean Peter F. Murray
Foothill College
12345 El Monte Road
Los Altos Hills, CA 94022

Dear Dean Murray,

It is with great enthusiasm and confidence that I support the application for the Awards for Innovation in Higher Education. Foothill College continues to broaden and deepen its reach across California and this current application provides a key opportunity for campus-wide support of one of my top priorities as president: to increase the recruitment, retention, and success of STEM majors, particularly students of color and women.

I have been in conversation with President Qayoumi of San Jose State, Engineering Dean Larson of Cal Poly San Luis Obispo, and Chancellor Blumenthal of the University of California, Santa Cruz regarding our mutual desire to transfer more students who earn bachelors degrees in STEM within four years. They are all strong supporters of a range of Foothill initiatives and are equally passionate about cultivating resident talent in Silicon Valley for the STEM pipeline to business and industry, public service, and advanced study.

To meet this commitment, Foothill will continue to expand its STEM programs, consistent with recent research on STEM student success and retention: academic support services that closely parallel STEM courses and pathways; analytical management to enable comprehensive support with limited resources; comprehensive mentoring services for progressive student success within an active learning community; stimulation of student learning via flipped classrooms, actively learning and growth mindset; and undergraduate research and internships. This will include:

- Recruiting more students into STEM majors by using faculty as STEM role models, especially for underrepresented students. These include the Puente Program (helps Latino students transfer to four-year institutions), Pass the Torch (pairs high achieving students with minority students in study teams), and an active Student Outreach and Retention Office.
- Giving students academic support with a dedicated "STEM emporium" space: STEM programs will apply a scaffolding strategy that includes readiness testing for core STEM courses, along with booster modules to get students' skills up to course requisite skill level. A STEM emporium is in a centralized physical location and has a mechanism to coordinate student assessments, booster/scaffolding instruction, and mentoring. The STEM emporium

12345 EL MONTE ROAD, LOS ALTOS HILLS, CALIFORNIA 94022-4599 • (650) 949-7200 • FAX (650) 948-4244

works in close collaboration with each student's instructor to ensure that remedial work has been completed and that the student has gained the skills to join and succeed with the other class participants.

- Expanding opportunities for STEM research and internships through partnerships: Foothill has developed partnerships with local four-year institutions and companies to provide collaborative studies, undergraduate research, and internships, including Stanford University, California State University at San Jose, Cal Poly San Luis Obispo, University of California Santa Cruz, University of California Irvine, University of California San Francisco, NASA AMES, Cisco, Microsoft, Triple Ring, and Fogarty Institute for Innovation. Foothill stays on the forefront of STEM education with relationships with the Carnegie Foundation for the Advancement in Education, Gates Foundation, Monterey Institute for Technology and Education, League for Innovation and the National Science Foundation.
- Supporting the ability of STEM teachers to continue to improve their instructional practices: Foothill's Science Learning Institute (SLI) provides an innovative model based on educational research and best practices for the successful teaching and learning of science, technology, engineering and mathematics at all levels. This includes STEM summer camps, scholarships, summer Math Bridge, online course creation, using the campus as a living laboratory, and cutting edge curriculum in biomedical devices, 3D printing, green chemistry, Big Data, quantum computing, and renewable/alternative energy.

Foothill College is in complete support of the application for the Awards for Innovation in Higher Education. I am also pleased to report that the White House published the above set of commitments as part of the College Opportunity Day of Action on December 4, 2014. The Commitments to Action on College Opportunity report can be found online (Foothill is on page 99): http://www.whitehouse.gov/sites/default/files/docs/college_opportunity_commitment_report.pdf

Please feel free to contact me if I might provide additional information and assurances to demonstrate our deep institutional commitment to these urgent issues.

Sincerely,

Judy C. Miner, Ed.D.
President

CAL POLY
SAN LUIS OBISPO

California Polytechnic State University
San Luis Obispo, CA 93407-0350

Office of the Dean
College of Engineering
805.756.2131

December 8, 2014

Peter Murray
Executive Dean, Foothill College
12345 El Monte Road
Los Altos Hills, CA 94022

Dear Dean Murray:

On behalf of Dr. Debra Larson, Dean for the College Engineering, California Polytechnic State University, I am writing to express support for the Foothill College's application for the **Innovation in Higher Education award**. It is my understanding that you are already collaborating with our Biomedical Engineering program. I am sure that this collaboration will help build the resources for a successful academic program for STEM track students both at Foothill College and Cal Poly. The increased success in two-year STEM programs at Foothill College will further lead to increased success for transfer students in our engineering programs at Cal Poly.

We are actively working to reduce the time to graduation for our engineering students. Collaboration between our programs has the potential to reduce time to graduation for transfer students from Foothill College to Cal Poly because of articulation of Foothill's Biomedical Device Engineering courses with relevant Cal Poly BMED courses, and availability of a wide range of engineering and other support courses during academic year and summer at Foothill College.

In support of the application, we can offer the following collaborative activities with Foothill College:

- Continue to expand our Engineering course to course articulations to reduce the number of courses Foothill and other community college students need to complete after transfer with the goal of true 2 + 2 pathways.
- Provide graduate and undergraduate student guest speakers from Cal Poly to Foothill College for focused lectures and seminars.
- Encourage Cal Poly faculty to participate in Foothill College's annual STEM Lecture Series to which Foothill College will invite high school students and their parents.
- Invite Foothill College students to Cal Poly for annual Biomedical Expo Day.
- Work within our available resources to expand the number of BMED labs at Cal Poly.
- Assist Foothill College in forming a mentorship program to connect high school and college students with university students who went through the same experience, and get advice or spend a day at the university shadowing that student.

- Work with Foothill College to develop joint internships, where students from Cal Poly and Foothill College will collaborate on the same project/study while working with medical doctors and research and development engineers.

Professor Richard Savage, chair of the Biomedical and General Engineering department will be the Cal Poly point of contact with respect to your application. Professor Savage will also work with you to identify and seek needed external support for our collaboration.

Sincerely,

Rakesh K. Goel, Ph.D., PE, F. ASCE, F. SEI
Associate Dean, Research, Graduate Programs, and Personnel
College of Engineering
California Polytechnic State University
San Luis Obispo, CA 93407-0350

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

SCHOOL OF MEDICINE
DEPARTMENT OF NEUROLOGY

January 04, 2015

Peter Murray
Executive Dean, Foothill College
12345 El Monte Road
Los Altos Hills, CA 94022

Dear Dean Murray:

As Director of the Neuroscience Diversity Scholars Program at University of California San Francisco, I am in complete support of your **application for the Innovation in Higher Education award**. Our collaboration will continue to help build the resources for a successful academic program for STEM track students. Early exposure of high school and community college students to research and entrepreneurship in our Neuroscience Program and California Institute for Quantitative Biosciences (QB3) will promote success and persistence to achieve their STEM BS in 4 years after entering college. Hopefully, many of these students will continue to advance degrees in STEM.

In support of the application we can offer these resources:

- Invite graduate students and Faculty to Foothill College for focused lectures and seminars. UCSF's Dr. Elizabeth Blackburn, Nobel Laurate is already scheduled for May 2015.

- Accept underrepresented, financially challenged and veteran students at Foothill College and Eastside Prep Charter High School to UCSF for 6 weeks in the 2015 summer. We will focus on students interested in biology, physical sciences, neurosceince, engineering, computer sceince and pre-med:
  - seminars every week (with food)
  - one day/week visit to QB3
  - four rotations where students have hands-on experience
  - end of the day time to reflect and encourage student's persistence in getting their BS

- Form a mentorship program where high school and college students can connect with graduate students who went through the same experience, and get advice or spend a day at the university shadowing that student.

- Introduce joint internships, where UCSF/Neurosceince and Foothill College will collaborate on the same project/study while working with medical doctors and research and development engineers.

Sincerely,

Sohila Zadran, PhD
Adj Assistant Professor
Department of Neurology
California Institute of Quantitative Bioscience (qb3)

Fogarty Institute
for Innovation

Melchor Pavilion
2490 Hospital Drive
Suite 310
Mountain View
California 94040

www.fogartyinstitute.org

December 16, 2014

Peter Murray
Executive Dean, Foothill College
12345 El Monte Road
Los Altos Hills, CA 94022

Dear Dean Murray:

As the President and CEO of the Fogarty Institute, I am in complete support of your application for the Innovation in Higher Education award. Here at the Fogarty Institute for Innovation, we build upon Dr. Fogarty's experience (Dr. Fogarty received the National Medal of Technology and Innovation from President Obama in November 2014) to provide a streamlined path for entrepreneurial innovators working on promising new medical therapies. We offer mentorship at every step of the process, providing access to expert intellectual, physical, and financial resources to propel medical concepts from initiation to application. Our collaboration will continue to help build the resources for a successful academic program for STEM track students. Early exposure for community college students to product innovation in our College Internship program will promote success and persistence.

In support of the application, we would be pleased to offer the resources listed below using an arrangement to be agreed upon later:

- Invite members from Fogarty and porfolio companies to Foothill College for focused lectures and seminars. One of our porfolio companies, nVision has used Foothill's Instron instrument and will be a guest speaker. nVision is an early-stage, venture backed medical device company that is dedicated to building a portfolio of novel and proprietary technologies to fill the void in female health-related innovation.
- Accept students at Foothill College to the Fogarty Institute for 6 weeks in the 2015 summer. Summer internships for college and high school students are designed to provide valuable on-the-job experience for young people who are just starting to explore career options. These programs can be a fun and exciting first step toward furthering your education and figuring out what direction you want to take in life. We will focus on students interested in biology, physical sciences, neurosceince, engineering, computer sceince and pre-med.

Sincerely,

Ann Fyfe
President and CEO
Fogarty Institute for Innovation

Appendix B:
Additional Materials on Section 3: Innovations Prior to January 2014

Scholarships:

The primary goal of Foothill's STEM scholarship program is to provide financial and academic support to at-risk students so that they are better able to pursue their chosen STEM field of study. The scholarships enable students who ordinarily are required to work in jobs unrelated to their studies the opportunity to focus 100% of their attention on their academic pursuits. The project proposes to recruit and retain students in STEM fields of study and to support their successful completion of required lower division STEM major coursework prior to transfer:

a. Recruit applicants who demonstrate both financial need and competency in STEM coursework.
b. Retain and support STEM students to successful completion of their coursework and encourage their advance toward careers in their chosen STEM fields.

Eight students have received STEM scholarships since its inception in the Fall of 2013. In addition to receiving financial support, these students received additional support in the form of mentoring, priority consideration for internships, academic services and community building activities.

In Fall 2013, all first quarter calculus scholar students were invited to a Meet and Greet with their calculus instructors held prior to the start of the quarter. Students were introduced to all the instructors as a resource for support. Instructors shared office hours, in addition to holding office hours in the STEM Success Center for drop in tutoring throughout the quarter.

Mentorship:

In the Fall 2013 quarter, an email was sent to all part-time and full-time faculty to recruit mentors. An initial mentoring survey was then sent to faculty who expressed interest in mentoring.

The mentoring program was described to faculty as a program whose objectives were: 1) to foster a relationship in which the student feels that there is someone on the faculty who cares about his or her academic success, and to whom he or she can turn to when the need arises. 2) to assist students in adjusting to college life; and 3) to foster student retention by creating a welcoming and supportive atmosphere.

The main role and responsibilities of the faculty mentor were outlined as:

- to communicate with mentees regularly
- to meet in person 3 times per quarter and via email as needed
- to advise mentee in exploring and reaching academic goals (Informal assistance will be provided, any specific questions regarding classes, or graduation or transfer requirements, etc. should be referred to the counselor)
- to assist mentee with the exploration of career goals
- to act as resource for mentee to get connected to on-campus (i.e. STEM Success Center (drop-in tutoring and workshops), other tutoring support services,

counseling, student groups and resources) and off-campus opportunities (i.e. internships, research, community service, awards and competitions)

A survey similar to that sent to faculty was also sent to the scholarship recipients. Both students and faculty were asked questions to gain more information on their background and interests. Using these survey results, students were matched up with their faculty mentor based on their intended major, interests, or working relationship. An email was sent to the mentor and mentee pair giving them guidelines for the mentoring program and instructing them to set up their first meeting.

Faculty members were given access to a webpage (created through Blackboard) where relevant mentoring documents were posted. In addition, faculty members were asked to complete a short checklist through the web page after each mentoring meeting with the student. This was done to keep track of the meetings and to afford a place where faculty could write any notes or comments about the student or mentoring relationship as the quarters progressed. A subset of the 12 faculty mentors regularly updated this online checklist to indicate their meetings with the students (see table below). In the future, a better interface will probably improve this response rate as the survey system through Blackboard was rather slow and not very user-friendly.

For the first meeting, students and faculty were asked to discuss and sign a mentoring contract that included guidelines for mentoring and expectations of both the student and faculty mentor. Students and faculty were advised to meet a minimum of 3 times with their mentee (weeks 1-3, 4-7 and 8-11). In practice, students and mentors met once in the Fall 2013 quarter (since it took a few weeks to get the mentors identified and matched up) and then 3 times each for the Winter and Spring 2014 quarters. Online reporting of these meetings reported that 75% of these meetings occurred in Winter, and 80% in Spring. This is most likely a low estimate, as some faculty mentors met with their students but did not report the meeting online.

Impacts and Evidence: Prior to 1/2014 (Detailed)

- Impact: Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program.

  Indicators to 1/2014: Target math graduation: increase 5% to 14%, from projected baseline of 125 to 132

  After the first project year (10/2012 - 9/2013), the key goal of increased student success was ahead of targets as stated in the project's proposal, even though unavoidable circumstances set back project development in its first year. The graduation rate of math students in the first full (2-year) student cohort increased by 26.7% over the previous year, which exceeded the target increase of 17.5% over baseline.

  Though earlier baseline figures are not available, the project's first year can approximate a baseline because of unavoidable delays in fully starting the program. Thus the project's Year-1 was more of a pilot year than a fully functional project year, because funding started months after the start of the academic year, and because of two unpredictable and major shifts in the infrastructure of the project:

the unexpected and sudden passing of the project Co-PI Ion Georgiou, and statewide changes in Learning Management System (LMS) policies.

Data from Foothill research showed positive association between students' success in the math sequence and participation in STEMWay Emporium services, with added value from increased participation in the Emporium. Data showed a moderate but steady correlation between amount of Emporium usage and success in Math-1: students who used Emporium 5 hours or more succeeded in Math-1 at about a +13% rate over those participating under 5 hours.

- Impact: Establish Emporium and increase Emporium usage.

  Indicators to 1/2014:

  Year 1 start: Begin faculty training for use of STEMWay. Mentors active in emporium.

  Year 1: Target emporium usage (% of key STEM course enrollment): 10%

  The STEMWay Emporium started with workshops and tutoring at the start of project, and grew to full service and visibility following the hiring of a full-time permanent director, Eric Reed, halfway through project Year-1 (the late start because of the project beginning well into the academic year). It is also called the STEM Success Center, and because of continuation from an earlier form it is also locally called PSEC for Physical Sciences and Engineering Center. Mentoring services were added, led by chemistry professor Sandha Rao and partly funded through a supplemental S-STEM grant from NSF. Usage of the key Emporium services, workshops and/or tutoring, among Math 1A students was 42% in Year1 (100 of 240), which was far above the target in the project proposal.

- Impact: Increase Emporium diagnostics and instruction and services.

  Indicators to 1/2014:

  Year 1 start: Emporium readiness testing, booster/scaffolding for 1 calculus course.

  Month 4: Emporium readiness testing, booster/scaffolding for 2 calculus courses.

  STEMWay focused on using workshops, tutoring, and mentoring for students. Workshops were created to cover booster/scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses. Readiness testing, diagnostics, and booster/scaffolding were handled in a distributed and hands-on approach, while assembling best materials for each purpose. (See "Lessons Learned" for specific successful strategies.)

Foothill College, Biomedical Device Program

Fall 2013 - Fall 2014

To launch a successful and innovative Biomedical Devices program at Foothill College, faculty and the Dean of Physical Sciences, Engineering and Math met and received advice from Silicon Valley industry leaders in innovation and entrepreneurs. The advisory board was formed to continue receiving valuable feedback and insure the growth of the program into specialties that are in need of workforce expansion.

One of the first in-person meetings was with Dr. Thomas Fogarty, the nationally renowned inventor of the balloon catheter. Just a few months ago, Dr. Thomas Fogarty was awarded the Presidential National Medal of Technology and Innovation, which is the country's highest honor for achievement and leadership in advancing the fields of science and technology. In the meeting, Dr. Thomas Fogarty supported the efforts in developing the program as well as outlined the importance of connection with regulatory agencies.

Dr. Michelle Khine, serial entrepreneur and UC Irvine associate professor of biomedical engineering, chemical engineering and materials science visited Foothill College in March of 2014. She gave an exciting and informative open to public lecture in which she discussed the growing need to cultivate "homegrown" STEM student innovators. She encouraged students to pursue STEM educational and entrepreneurial opportunities. Dr. Khine also supported efforts in developing the program. Foothill faculty later visited UC Irvine and also welcomed one of Dr. Khine's Ph.D. students for a guest lecture in their first Introduction to Biomedical Engineering Course.

Additionally, Foothill faculty and engineering students visited medical device development and manufacturing facility, Phoenix DeVentures Inc. in Morgan Hill, CA. The company provides range of services for designing, developing and manufacturing of medical devices. The faculty discussed the details of the program with CEO Jeff Christian, who also supported the efforts and provided valuable feedback and lessons learned in this area.

During the course development period, the faculty outreached to Anoka Ramsey Community College located in Coon Rapids, MN. The college has several tracks and pathways for biomedical technician training which graduated over 1000 students in the last 10 years. The faculty successfully exchanged the lessons learned and welcomed Foothill College to their Community College Consortium consisting of dozen of community colleges across the nation with similar programs.

On several occasions, the faculty and the Dean traveled to CSU San Louis Obispo (SLO) to learn about their famous hand-on program in biomedical engineering. The CSU SLO faculty gave a tour of their engineering and machining laboratories, demonstrated student projects and even shared their curriculum and laboratory exercises for their introductory courses. They showed support for the program and invited our students and faculty to join them for their Expo Day.

Foothill College faculty wrote course outlines based on Anoka Ramsey Community College courses for biomedical technician training and CSU SLO courses in biomedical engineering. The five course sequence consisted of the following courses:

- *ENGR83A: Introduction to Biomedical Engineering*
- *ENGR83B: Design and Manufacturing in the Biomedical Engineering Field*
- *ENGR83C: Introduction to Medical Device Regulations*
- *ENGR83D: Introduction to Quality Assurance*
- *ENGR83E: Introduction to Documentation*

The curriculum and the Certificate in Proficiency were approved and the program officially started in the Fall of 2014. ***Two of the courses received one-to-one articulation with CSU SLO courses. Foothill College is the only college that holds articulation to biomedical engineering courses at CSU SLO. The goal of this articulation agreement is to graduate transfer students in 4 years by allowing them to take all introductory undergraduate classes in major at Foothill College.*** *Table 1 shows CSU SLO biomedical engineering curriculum for the first 2 years and highlights courses that are articulated with Foothill College. On regular basis, the faculty and the Dean meet with new industry leaders and entrepreneurs and continue building stronger relationship with the industry. Currently, they are working on establishing internships for students who complete the sequence in the Spring of 2015.*

Table 1: CSU SLO biomedical engineering curriculum for the first 2 years with highlighted courses that are articulated with Foothill College.

Fall	Winter	Spring	Fall	Winter	Spring
Introduction to the Biomedical Engineering Major **BMED 101 (1)**	*Introduction to Biomedical Engineering Analysis* **BMED 102 (1)** (BMED 101, MATH 141)		*Introduction to Cell & Molecular Biology* **BIO 161 (4)** (Recom: CHEM 110, 111, 124 or 127) [B2/B4]	*Introduction to Biomedical Engineering* **BMED 212 (3)** (MATH 143 or Instr. consent)	*Mechanics of Materials I* **CE 204 (3)** (ME 211)
Calculus I **MATH 141 (4)** * [B1]	*Calculus II* **MATH 142 (4)** (MATH 141 w/min C-) [B1]	*Calculus III* **MATH 143 (4)** (MATH 142 w/min C-) [Add'l Area B]	*Calculus IV* **MATH 241 (4)** (MATH 143)	*Linear Analysis I* **MATH 244 (4)** (MATH 143)	Approved Support Elective **(4)**[2]
	General Physics IA **PHYS 141 (4)** (MATH 141 w/min C-; MATH 142† or 182†) [Add'l Area B]	*General Physics II* **PHYS 132 (4)** (PHYS 141)	*General Physics III* **PHYS 133 (4)** (PHYS 131, HNRS 131, or PHYS 141; MATH 142. Recom: MATH 241)	*Programming for Engineering Students* **CSC 231 (2)** (MATH 142;PHYS 121, 131, or 141)	*Electric Circuit Theory* **EE 201 (3)** (MATH 244, PHYS 133)
General Chem. for Engr. I **CHEM 124 (4)*** **OR** *General Chemistry I* **CHEM 127 (4)*** [B3/B4]	*General Chem. for Engr. II* **CHEM 125 (4)*** **OR** *General Chemistry II* **CHEM 128 (4)***	**GE (4)** **		*Engineering Statics* **ME 211 (3)** (MATH 241†, PHYS 131 or 141)	*Engineering Dynamics* **ME 212 (3)** (MATH 241; ME 211 or ARCE 211)
	Engineering Design Communication **ME 228 (2)**			**GE (4)** **	**GE (4)** **
Expository Writing **ENGL 133/134 (4)**** [A1] Can be taken anytime during Freshman Year					
Oral Communication **COMS 101/102 (4)**** [A2] Can be taken anytime during Freshman Year					
	Technical Writing for Engineers **ENGL 149 (4)** [A3] (Completion of GE A1 with a C- or better, Recommended: Completion of GE A2) Can be taken anytime between Winter of Freshman and Winter of Sophomore Years				
13	15	16	16	16	17

Prior to 2014/2015 academic year

The courses were proposed during Spring 2014. The courses were articulated in the Fall of 2014.

Fall 2014

ENGR83A: Introduction to Biomedical Engineering

In this class, the students were introduced to a wide variety of problems that biomedical engineers solve. It covered a variety of applications, such as, implantable devices, bioinstrumentation, and biomaterials. It provided a general understanding of the biomedical device industry in terms of its size and scope, current trends and the wide range of products involved with emphasis on biomedical companies in California.

It also provided an overview of the development of a medical device from initial conception through development, testing, validation, manufacture, clinical trials and final approval by regulatory agencies.

The students also worked on a final project that involved developing a tooth brush handle for youth individuals with disabilities. At the end of the quarter, thirteen groups presented their prototypes to a panel judges comprising of executive Dean, dental hygiene faculty and students at Foothill College. The prototypes were developed using various technologies and materials, such as, 3D printers, thermoplastic, silicone rubber and others. Two out of thirteen projects were selected to go on to the next phase and are currently reaching out into public for additional feedback.

Additionally, the class received a number of guest lectures from the industry and the government as well as visited PathServe Bioskills Lab in San Carlos, hosted by Dr. Roman Karp. The guest speakers included;

- *Albert Chin M.D.*
- *Ken Skodacek , U.S. FDA, CDRH*
- *Keith Sardo, Hanger Clinic*
- *Yana Dutt-Singkh, M.D.*
- *Catherine Draper, Professional Dental Hygienist*
- *Natalie Wisniewski Ph.D.*
- *JC Sun*
- *Himanshu Sharma Ph.D.*

Winter 2015

ENGR83B: Design and Manufacturing in the Biomedical Engineering Field

An introduction to the design and manufacturing of medical devices with special focus on the unique design manufacturing challenges that are necessary to achieve World Class Manufacturing excellence. Describes the fundamental systems used in the design, development, and manufacturing of medical devices and how these relate to industry regulations. Specific topics include: material and process selection considerations, aseptic processes, clean-room techniques, sterilization processes, clinical testing, lot traceability, introduction to automation and control systems, testing and instrumentation lab and manufacturing controls.

ENGR83C: Introduction to Medical Device Regulations

Introduction to certification standards and the agencies involved in the regulatory processes specific to the medical device industry. Topics include Food and Drug Administration regulations, international regulations and quality certification processes.

Spring 2015

ENGR83D: Introduction to Quality Assurance

Provides students with an in-depth understanding of the role quality plays in an industrial environment regulated by the Food and Drug Administration (FDA). The responsibilities of quality assurance during the engineering, manufacturing, and production of a product. Topics will include management responsibilities, design control, production and process controls, continuous improvement, and methods and tools used to support quality assurance. The ISO standards, the regulatory requirements mandated by the FDA.

ENGR83E: Introduction to Documentation

This course focuses on establishing and managing documentation and related systems in the area of medical device manufacturing. Fundamentals of governmental requirements that impact medical device documentation, the benefits and elements of a documented configuration management system, and the details to establish related systems, policies and tools.

Certificate of Proficiency

Summer 2015

Potential Internships

University of California at San Francisco (20)
University of California at Irvine (2)
Fogarty Institute of Innovation (3-5)
Triple Ring (3)
Hanger Clinic (2)
On Campus Internships (4)

Appendix C:
Additional Materials on Section 4: Innovations Since January 2014

Detailed Impacts and Evidence on Strategic STEMWay Project: in 2014

- Impact: Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program.

  Indicators to 1/2015: Target math graduation: increase 32% to 17.5%, from projected baseline of 128 to 172

  After the project's pilot test (10/2012 - 9/2013), the key goal of increased student success was ahead of targets as stated in the project's proposal, even though unavoidable circumstances set back project development in its first year. The graduation rate of math students in the first full (2-year) student cohort increased by 26.7% over the previous year, which exceeded the target increase of 17.5% over baseline. Halfway (1-year) figures of the project's second math student cohort suggest similar gains toward graduation. The data also supports a correlation between STEMWay Emporium services and increases in graduation rates.

  Data from Foothill researcher Elaine Kuo showed positive association between students' success in the math sequence and participation in STEMWay Emporium services, with added value from increased participation in the Emporium, and with increasing value from the project's Year-1 to Year-2.

  Success in the gateway course Math 1A is the key to the 3-course calculus series, Math 1A to 1C. in the first two years of Emporium operation, total student success in Math 1A rose by 8.5% in ratio, from 60% (145 of 240 starting) to 65% (191 of 296), 46 more total successes and 5 additional percentage points. Student participation in the primary Emporium services (tutoring and workshops) increased by +52% in ratio, from 42% (100) of Math 1A students to 64% (189), a numerical increase of 89, and 22 more percentage points. Student success in Math 1A was associated with usage of Emporium primary services, to a statistically significant level in Year-2: only slightly more users of Emporium succeeded in Math-1 in Year-1, but in Year-2, 73% of Emporium users succeeded, vs. 50% of those who did not use the Emporium. Data showed a moderate but steady correlation between amount of Emporium usage and success in Math-1: students who used Emporium 5 hours or more succeeded in Math-1 at about a +13% rate over those participating under 5 hours.

  While these are still early results, all point toward increasing usage of the Emporium, and to increasing success in the pivotal math courses by those students who do participate in the Emporium, and to improving success with more Emporium usage. The STEMWay PI and Researcher are gathering further data in the coming years to analyze the associations in more detail and also to test their persistence.

  International students (F1 visa) have had a higher success rate than domestic students so far, though both subgroups have a similar rate of improvement after using Emporium services (from 70% to 75% success for visa students, a +7.1% improvement, vs. 52% to 56% for domestic students, +7.7% improvement). Together these suggest the possibility of more self-selection among international

students, but similar value in using the Emporium for all participating students, which means good probability for continuing improvement among domestic students with increasing information and acceptance of STEMWay among them. The project will be looking more closely at the differences in value and in effect of various forms of services for the different subgroups in the coming year.

The relative effectiveness of tutoring or workshops has so far shown positive data for both. Year-1 data suggested more value for Emporium workshops, but Year-2 had a slight advantage for tutoring. Tutoring was used by considerably more students in Year-2, which suggests that either students as a whole are getting more comfortable with using the Emporium as individuals, or that Emporium tutoring has been improving considerably, or both. Further data in the next year should help explain the differences.

The Emporium added a new "Acceleration" program to help students start college math at a higher math course, and so have a greater chance to persist and graduate. This is discussed further under "Results: Increase Emporium Diagnostics and Instruction and Services."

- Impact: Increase STEM Course Enrollment.

  Indicators to 1/2015: Target STEM course enrollment increase: 5%

  Enrollment in Foothill College's math program increased beyond targets in the project's first two years. Gateway course Math 1A enrollment in the baseline year 2011-12 was 645; in the project's first year 2012-13 this increased by 5.7% (682), and in the second year 2013-14 by another 18.2% (806), or 25.0% (161) over baseline. This far exceeds the goal of the proposal, and is even more remarkable in that total enrollment at the college went in the other direction, decreasing -8.2% in project Year-1 (15,500 to 14,228) and by another -6.2% in Year-2 (to 13,347), a decrease of -14% in two years, vs. the core math sequence increase of +25%. Other factors are involved and there are no explicit data on the direct effect of STEMWay on student enrollment in math, but the growing usage of the Emporium suggests a positive effect, and progress toward this goal has certainly been a strong success after two project years.

- Impact: Establish Emporium and increase Emporium usage.

  Indicators to 1/2015: Target emporium usage: 20% of STEM course enrollment

  The STEMWay Emporium started with workshops and tutoring at the start of project, and grew to full service and visibility following the hiring of a full-time permanent director, Eric Reed, halfway through project Year-1 (the late start because of the project beginning well into the academic year). It is also called the STEM Success Center, and because of continuation from an earlier form it is also locally called PSEC for Physical Sciences and Engineering Center. Mentoring services were added, led by chemistry professor Sandha Rao and partly funded through a supplemental S-STEM grant from NSF. Usage of the key Emporium services, workshops and/or tutoring, increased among Math 1A students from 42% in Year1 (100 of 240) to 64% in Year-2 (189 of 296). These figures are far above the targets of

the project proposal. In Year-2 the number of Foothill College students who used the Emporium heavily (over 12 hours) increased by 65%.

The Emporium Director, the project and the department have succeeded in increasing usage of the center by steps including these:

- Expanded availability: from 37 open hrs/wk in Year-1, to 59.5 hrs/wk in Year-2.
- Improved Emporium facilities:
  - The physical size increased in response to growth in general and workshop usage. However, student usage is growing faster than the facilities, and at times general use areas are overcrowded, especially mid-term.
  - Added more courseware: in Math, over 100 student computers with software such as MatLab, Mathematica, SolidWorks, and programming software; in Biology, an inventory of anatomy models and slides.
- Expanded Emporium communication and outreach:
  - Open house each quarter; published schedule; public activities.
  - In-class visits, financial aid workshops, flyers.
  - Specialized workshops for STEM scholarship applications.
  - Financial aid informational workshops, with the financial aid department.

The Emporium Director had direct evidence of effectiveness of in-class visits promoting the Emporium: after increasing in-class visits in the winter term, Emporium usage increased more that term than in the fall. Implementation of the STEMWay Emporium has been succeeding far beyond targets, to the point of straining the college's ability to serve the continually growing amount of student interest.

- Impact: Increase Emporium diagnostics and instruction and services.

  Indicators to 1/2015: Emporium readiness for 3 calculus courses.

STEMWay focused on using workshops, tutoring, and mentoring for students. Workshops were created to cover booster/scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses. Readiness testing, diagnostics, and booster/scaffolding were handled in a distributed and hands-on approach, while assembling best materials for each purpose.

The proposed focus of STEMWay was to improve students' success in STEM courses by early identification of students' readiness for each course, diagnosis of knowledge gaps in the student, and filling any gaps through a booster/scaffolding approach by an LMS when possible and by tutoring otherwise.

The project has continued its approach in supplying complete out-of-the-classroom services, and focused instruction to fill knowledge gaps for students. It has shifted its focus from heavy use of a custom-programmed LMS to intensive instruction in workshops and by tutors. The best available LMS, by Blackboard, was not able to meet the targeted needs of the STEMWay scaffolding approach; the state of California is directing an Online Education Initiative (OEI) which will include a new statewide LMS portal and in which STEMWay PI Silverman will be directly involved.

In the meantime, STEMWay will revert to the Etudes system (from El Camino College) that is in general use at Foothill College for basic instruction, and will be seeking to provide online products (possibly EdReady) to give additional tutorial support for students. The sudden loss of Co-PI Georgiou, who had been directing the LMS usage for STEMWay, was temporarily crippling for the use of the Blackboard LMS in the project, but in any case the project was moving from Blackboard to the future OEI. While this has shifted the project's focus for its first few years, in the long run it should be beneficial to join with and move to OEI.

In the meantime, STEMWay's focus on workshops, tutoring, and mentoring has been compensating for the temporary lack of a customizable LMS. Workshops have been created to cover booster/scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses.

The active usage and apparent value for students seems due largely to the full-service approach of STEMWay, to the active and responsive Director of the Emporium / PSEC, and active faculty collaboration fostered by the approach adopted by project PI Silverman of "Growth Mindset." The latter is an approach of persistence in learning, promoted by the Carnegie Foundation and brought to STEMWay and other Foothill College staff. Mentoring has increased, with a schedule of instructors based on demand managed by the Emporium Director, and covering several subjects in addition to math.

Without a full LMS, readiness testing, diagnostics, and booster/scaffolding have been handled in a more distributed and hands-on approach, while still assembling best materials for each purpose. Some methods that contributed to the effectiveness of the Emporium in aiding STEM students:

- Workshops covering math, chemistry, and biology courses in booster / scaffolding. There was a large response, over 200 students at each session. Responses from students to the Emporium Director include several saying that they would not have passed their course without the workshop. One student said he would not have attempted the class if a workshop was not available.
- "Early alert" program: Instructors email a list of students needing help in a subject to the Emporium Director, who contacts them by email or phone. About 40% of students new to the center have used it after being contacted.
- A "Foundations lab" to support students in pre-college level math classes. The center targeted 6 sections of Pre-Calculus for embedded tutoring: targeted students had a 59% success rate, while others not targeted had 44% success rate.
- "Test corrections" mastery instruction system: Students can recover lost points on an exam. They must orally defend their new answers, as well as explain previous answers. Instructors say that "through this process students develop deeper understanding and confidence in the subject and in their answers."
- Acceleration program: a summer bridge program to help students start college with credit for a higher math course, and so have a greater chance to persist and graduate. In two sessions, 70% of students (of 130) increased 1+ level.

- The Emporium maintained worksheets for students covering course subjects.
- Peer-tutoring: Started with Math; expanded to cover new subjects.
- Integrated Emporium activities into Math 1A classes: created Readiness testing and scaffolding activities with Math 1A faculty, and added Workshops for 1A.
- Feedback to and from instructors, to improve teaching and Emporium offerings: the center added a computer science workshop on algorithms and data structures based on instructor feedback.
- Practice sessions with faculty on best practices in providing support: Role-play effective tutoring strategies, test corrections, and supporting a growth mindset. Instructors have given very positive responses.
- Coordinating with the "Teaching and Learning Center" for integrated and consistent services: the two centers collaborated on recruiting, staffing, using and improving the SARS system to track students, and on the campus embedded tutoring program.
- Diversification in professionals: Hired two minority instructors in subjects that previously had none. One reported that "it made a difference for Math 105 students who were happy to see a Hispanic instructor in the center."
- Internal Advisory Committee (IAC): The department's advisory board made improvements to the test corrections process, obtained resources from instructors to support workshops, and redesigned a workshop based on instructors' ideas.

- Impact: Provide STEMWay Internships.

  Indicators to 1/2014: Begin STEMWay internships.

  Internship programs were made available at Foothill College in 2013-14, including research internships at Stanford University, University of California Santa Cruz Advanced Systems Laboratory, San Jose State University, and San Jose Technical Museum. An internship building block was installed in the math LMS in Fall 2013 (and will also be provided in the interim Etudes LMS in Fall 2014), along with Foothill College's own internship department.

Lessons Learned In STEMWay, 2014:

- Student subgroups differ in incoming academic work habits, but all can be reached and improved at similar growth rates.
  - International students (with an F1 visa) using STEMWay had a higher success rate than domestic students in Year 1, though both subgroups had a similar rate of improvement after using Emporium services (from 70% to 75% success for visa students, a +7.1% improvement, vs. 52% to 56% for domestic students, +7.7% improvement). Together these suggest the possibility of more self-selection among international students, but similar value in using the Emporium for all participating students, which means good probability for continuing improvement among domestic students with increasing information and acceptance of STEMWay among them. The project will be looking post-2014 more closely at the differences in value and in effect of various forms of services for the different subgroups in the coming year.

- Usage of the central academic aid center can and was increased significantly by several specific steps:
    - Expanded availability: from initially 37 open hours/week to 59.5 hours/week.
    - Improved Emporium facilities:
        - Physical size increased in response to growth in general and workshop usage. However, student usage is growing faster than the facilities, and at times general use areas are overcrowded, especially mid-term.
        - Added more courseware: in Math, over 100 student computers with software such as MatLab, Mathematica, SolidWorks, and programming software; in Biology, an inventory of anatomy models and slides.
    - Expanded Emporium communication and outreach:
        - Open house each quarter; published schedule; public activities.
        - In-class visits, financial aid workshops, flyers.
            - Direct evidence of the effectiveness of in-class visits promoting the Emporium: after increasing in-class visits in the winter term, Emporium usage increased more that term than in the fall. Implementation of the STEMWay Emporium has been succeeding far beyond target goals, to the point of straining the college's ability to serve the continually growing amount of student interest.
        - Specialized workshops for STEM scholarship applications.
        - Financial aid informational workshops, with the financial aid department.
- A central students' academic aid center (Emporium) can improve students' success by continually improving diagnostics, tutoring, counseling, and community services, without relying on programmed systems and materials (LMS).

  STEMWay's approach is to supply complete out-of-the-classroom services, and focused instruction to fill knowledge gaps for students. It shifted its focus from heavy use of a custom-programmed LMS to intensive instruction in workshops and by tutors. The best available LMS, by Blackboard, was not able to meet targeted needs of the STEMWay scaffolding approach. The state of California is directing an Online Education Initiative (OEI) which will include a new statewide LMS portal and in which STEMWay PI Silverman will be directly involved, and meanwhile STEMWay reverted to the Etudes system (from El Camino College) that is in general use at Foothill College for basic instruction, and STEMWay focused on workshops, tutoring, and mentoring. Workshops were created to cover booster/scaffolding for all 3 calculus courses.

  The active usage and apparent value for students was due largely to the full-service approach of STEMWay, to the active and responsive Director of the Emporium / PSEC, and active faculty collaboration fostered by project PI Silverman (following Year 1, the project added "Growth Mindset" strategy: an approach of persistence in learning, promoted by the Carnegie Foundation and brought to STEMWay and other Foothill College staff). Mentoring was heavily used, with a schedule of instructors based on demand managed by the Emporium Director, and covering several subjects in addition to math.

External Evaluation Report

Dr. Robert London, External Evaluator
Project: NSF 1161220 in STEM
STEMWAY: Comprehensive Academic Support for STEM students
PI: Loretta Silverman, Foothill College
For Annual Report: Oct 2013 - Sep 2014

Introduction

After a stalled start and some serious difficulties in getting to full speed, STEMWay in its second year has begun to embody the full-supplement, total-coverage educational approach that had been proposed. From early data, both qualitative and quantitative, it appears that STEMWay is fully on its way toward its proposed goals, and possibly going well beyond them. Despite missing the original Co-PI and also two key ingredients from the proposal's model, the project seems to be compensating with a highly complementary approach, and with additional factors that emphasize feedback and formative improvement.

This evaluation focuses on assessing progress first toward the project's primary goal of improving student success rates in STEM subjects, and then toward secondary goals such as increasing student enrollment and usage of student services. Since the five-year project has just completed two years, qualitative data and trends in quantitative data with nonsignificant results are fully considered. Taken as a whole, the data supports successful directions in the project, both in the educational model as proposed and in factors that were not highlighted in the proposal. Those are discussed in the report's Conclusion.

Findings

This section summarizes the project's main goals and then evaluates progress toward those goals, which are grouped by type. (Note: the central service of STEMWay is named here as in the project proposal, as the "Emporium." In some references that are quoted here, the same central service is also named the "STEM Success Center," or "PSME Center" (Physical Sciences, Mathematics, and Engineering Center), or "PSEC" (Physical Sciences and Engineering Center). These are all equivalent.)

Project Goals and Objectives

The primary goals and objectives of the STEMWay project, as stated in the project proposal:

Primary Goal:

Increase graduation of STEM students in 2-year college programs by improving retention.

Approach:

A comprehensive outside-the-classroom academic support program for students.

Key Elements:

- Academic support services that closely parallel STEM courses and pathways.
- Early identification of student's deficiencies with an intensive intervention.
- Mentoring for progressive student guidance and an active learning community.
- Continual involvement by all STEM faculty members for collaborative improvement.
- Scientific management to enable comprehensive support with limited resources.

Focus:

- Improving student success by filling knowledge gaps.

Specific Goals, with Indicators and Benchmarks:

- Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program. *Indicators:*
  - Year 1: Target math graduation: increase 5% to 14%, from projected baseline of 125 to 132
  - Year 2: Target math graduation: increase 32% to 17.5%, from baseline of 128 to 172
  - Year 3: Target math graduation: increase 69% to 22.5%, from baseline of 135 to 237
  - Year 4: Target math graduation: increase 88% to 25%, from baseline of 141 to 288
  - Year 5: Target math graduation: increase 95% to 26%, from baseline of 149 to 331
- Increase STEM course enrollment. *Indicators:*
  - Year 2: Target STEM course enrollment increase: 5%
  - Year 3: Target STEM course enrollment increase: 7%
  - Year 4: Target STEM course enrollment increase: 9%
  - Year 5: Target STEM course enrollment increase: 10.5%
- Establish Emporium and increase Emporium usage. *Indicators:*
  - Year 1 start: Begin faculty training for use of STEMWay. Mentors active in emporium.
  - Year 1: Target emporium usage (% of key STEM course enrollment): 10%
  - Year 2: Target emporium usage: 20%
  - Year 3: Target emporium usage: 30%
  - Year 4: Target emporium usage: 40%
  - Year 5: Target emporium usage: 50%
- Increase Emporium diagnostics and instruction and services. *Benchmarks:*
  - Year 1 start: Emporium readiness testing, booster/scaffolding for 1 calculus course.
    - Month 4: Emporium readiness testing, booster/scaffolding for 2 calculus courses.
    - Month 9: Emporium readiness testing, booster/scaffolding for 3 calculus courses.
  - Year 2 start: Emporium readiness testing, booster/scaffolding for 3 calculus courses.
    - Month 9: Emporium readiness testing, booster/scaffolding for 3 calculus.
  - Year 3 start: Emporium readiness testing, booster/scaffolding for chemistry courses.
  - Year 4 start: Emporium readiness testing, booster/scaffolding for physics courses.
  - Year 5 start: Emporium readiness testing, booster/scaffolding for computer science courses.
- Provide STEMWay Internships. *Benchmarks:*
  - Year 2 start: Begin STEMWay internships.
- Evaluate STEMWay quantitatively. *Benchmarks:*
  - Year 1 Month 9: Quantitative evaluation of STEMWay effect on student success for year 1.
  - Year 2 Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-2.
  - Year 3 Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-3.
  - Year 4 Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-4.
  - Year 5 Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-5.
- Disseminate project outcomes and consequences. *Benchmarks:*
  - Year 3 Month 9: Dissemination of mid-project outcomes.
  - Year 5 Month 9: Dissemination of project outcomes; report on success of STEMWay project.

Results of Primary Goal: Improving Student Successful Completions

Goal: Increase graduation in college math: associate degree or transfer into a baccalaureate STEM program, by improving retention. *Indicators:*

- Year 1: Target math graduation: increase 5% to 14%, from projected baseline of 125 to 132
- Year 2: Target math graduation: increase 32% to 17.5%, from projected baseline of 128 to 172

After the first two project years, the key goal of increased student success is ahead of targets as stated in the project's proposal, even though unavoidable circumstances set back project development in its first year. From current data, the graduation rate of math students in the first full

(2-year) student cohort increased by 26.7% over the previous year, which exceeded the target increase of 17.5% over baseline. Halfway (1-year) figures of the project's second math student cohort suggest similar gains toward graduation. The data also supports a correlation between STEMWay Emporium services and increases in graduation rates.

Though earlier baseline figures are not available, the project's first year can approximate a baseline because of unavoidable delays in fully starting the program. Thus the project's Year-1 was more of a pilot year than a fully functional project year, because funding started months after the start of the academic year, and because of two unpredictable and major shifts in the infrastructure of the project: the unexpected and sudden passing of the project Co-PI Ion Georgiou, and statewide changes in Learning Management System (LMS) policies.

The first available data for a student cohort, 2011-13, overlaps the start of the project in November 2012, and that first cohort may have had some effect from the first year of the STEMWay Emporium, but since it had relatively little availability for contact, that cohort is the best current approximation of a baseline. That cohort began the math sequence (Math 1A-1C) with 645 students, and within 2 years 16.9% (109) graduated. The next cohort, 2012-14, was the first full cohort with access to STEMWay, with 682 students starting Math 1A, and 21.4% (146) completing the sequence within 2 years, an improvement of 26.7% over the previous year. Although this was the project's first fully functioning year, the graduation figures were close to second-year targets: a gain of +37 students (2nd-year target = +44), and +27% (2nd-year target = +32%).

Data from project Researcher Elaine Kuo showed positive association between students' success in the math sequence and participation in STEMWay Emporium services, with added value from increased participation in the Emporium, and with increasing value from the project's Year-1 to Year-2. As stated in the project's Annual Report for Year-2 by project PI Loretta Silverman, increased success in student completions in the math sequence is one of the "Key Indicators Met."

Success in the gateway course Math 1A is the key to the 3-course calculus series, Math 1A to 1C. in the first two years of Emporium operation, total student success in Math 1A rose by 8.5% in ratio, from 60% (145 of 240 starting) to 65% (191 of 296), 46 more total successes and 5 additional percentage points. Student participation in the primary Emporium services (tutoring and workshops) increased by +52% in ratio, from 42% (100) of Math 1A students to 64% (189), a numerical increase of 89, and 22 more percentage points. Student success in Math 1A was associated with usage of Emporium primary services, to a statistically significant level in Year-2: only slightly more users of Emporium succeeded in Math-1 in Year-1, but in Year-2, 73% of Emporium users succeeded, vs. 50% of those who did not use the Emporium. Data showed a moderate but steady correlation between amount of Emporium usage and success in Math-1: students who used Emporium 5 hours or more succeeded in Math-1 at about a +13% rate over those participating under 5 hours, and this advantage was nearly the same in both years.

While these are still early results, they all point toward increasing usage of the Emporium, and to increasing success in the pivotal math courses by those students who do participate in the Emporium, and to improving success with more Emporium usage. The Annual Report points out that these results could be at least partly due to reverse causality, with some success-bound students choosing to use the Emporium for added advantage or out of curiosity. But the improvement in success rate, the faster growing usage of the Emporium, and the general advantage of increased usage in the Emporium all suggest direct value from the services there, rather than just self-selection, which would be less likely to lead significantly to increases over time. The STEMWay PI and Researcher are gathering further data in the coming years to analyze the associations in more detail and also to test their persistence.

International students (with an F1 visa) have had a higher success rate than domestic students so far, though both subgroups have a similar rate of improvement after using Emporium services (from 70% to 75% success for visa students, a +7.1% improvement, vs. 52% to 56% for domestic students, +7.7% improvement). Together these suggest the possibility of more self-selection among international students, but similar value in using the Emporium for all participating students, which means good probability for continuing improvement among domestic students with increasing information and acceptance of STEMWay among them. The project will be looking more closely at the differences in value and in effect of various forms of services for the different subgroups in the coming year.

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The Emporium added a new "Acceleration" program to help students start college math at a higher math course, and so have a greater chance to persist and graduate. This is discussed further under "Results: Increase Emporium Diagnostics and Instruction and Services."

Results: Increase STEM Course Enrollment

Goal: Increase STEM course enrollment. *Indicators:*

Year 2: Target STEM course enrollment increase: 5%

Enrollment in Foothill College's math program increased beyond targets in the project's first two years. Gateway course Math 1A enrollment in the baseline year 2011-12 was 645; in the project's first year 2012-13 this increased by 5.7% (682), and in the second year 2013-14 by another 18.2% (806), or 25.0% (161) over baseline. This far exceeds the goal of the proposal, and is even more remarkable in that total enrollment at the college went in the other direction, decreasing -8.2% in project Year-1 (15,500 to 14,228) and by another -6.2% in Year-2 (to 13,347), a decrease of -14% in two years, vs. the core math sequence increase of +25%. Other factors are involved and there are no explicit data on the direct effect of STEMWay on student enrollment in math, but the growing usage of the Emporium suggests a positive effect, and progress toward this goal has certainly been a strong success after two project years.

Results: Establish Emporium and Increase Its Usage

Goal: Establish Emporium and increase Emporium usage. *Benchmarks:*

Year 1 start: Begin faculty training for use of STEMWay. Mentors active in emporium.
Year 1: Target emporium usage (% of key STEM course enrollment): 10%
Year 2: Target emporium usage: 20%

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Results: Increase Emporium Diagnostics and Instruction and Services

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The proposed focus of STEMWay was to improve students' success in STEM courses by early identification of students' readiness for each course, diagnosis of knowledge gaps in the student, and filling any gaps through a booster/scaffolding approach by an LMS when possible and by tutoring otherwise. The proposal stated: "*STEMWay's first goal is to increase graduation in college math, with associate degree and/or transfer into a baccalaureate STEM program… STEMWay provides early and intensive student interventions by a* ***scaffolding*** *program, including* ***readiness testing*** *for the critical STEM math courses, along with* ***booster modules*** *to push students up to the course's requisite skill level…. Another important factor that will be evaluated is strategic optimization in applying limited resources; for example, how to allocate time for students so that all students needing academic support will be fully helped.*"

The project has continued its approach in supplying complete out-of-the-classroom services, and focused instruction to fill knowledge gaps for students. It has shifted its focus from heavy use of a custom-programmed LMS to intensive instruction in workshops and by tutors. In the Annual Report, PI Loretta Silverman explains the change in LMS strategy: the best available LMS, by Blackboard, was not able to meet the targeted needs of the STEMWay scaffolding approach; the state of California is directing an Online Education Initiative (OEI) which will include a new statewide LMS portal and in which STEMWay PI Silverman will be directly involved. In the meantime, STEMWay will revert to the Etudes system (from El Camino

College) that is in general use at Foothill College for basic instruction, and will be seeking to provide online products (possibly EdReady) to give additional tutorial support for students. The sudden loss of Co-PI Georgiou, who had been directing the LMS usage for STEMWay, was temporarily crippling for the use of the Blackboard LMS in the project, but in any case the project was moving from Blackboard to the future OEI. While this has shifted the project's focus for its first few years, in the long run it should be beneficial to join with and move to OEI.

In the meantime, STEMWay's focus on workshops, tutoring, and mentoring has been compensating for the temporary lack of a customizable LMS. Workshops have been created to cover booster/scaffolding for all 3 calculus courses, meeting the project's Benchmark. Workshops were also added for other math courses, and for chemistry and biology courses.

The active usage and apparent value for students seems due largely to the full-service approach of STEMWay, to the active and responsive Director of the Emporium/PSEC, and active faculty collaboration fostered by the approach adopted by project PI Silverman of "Growth Mindset." The latter is an approach of persistence in learning, promoted by the Carnegie Foundation and brought to STEMWay and other Foothill College staff. Mentoring has increased, with a schedule of instructors based on demand managed by the Emporium Director, and covering several subjects in addition to math.

Without a full LMS, readiness testing, diagnostics, and booster/scaffolding have been handled in a more distributed and hands-on approach, while still assembling best materials for each purpose. Some methods that appear to be aiding students and the effectiveness of the Emporium:

- Workshops covering math, chemistry, and biology courses in booster/scaffolding. There has been a large response, with over 200 students at each session. Responses from students to the Emporium Director include several saying that they would not have passed their course without the workshop. One student said he would not have attempted the class if a workshop was not available.
- "Early alert" program: Instructors email a list of students needing help in a subject to the Emporium Director, who contacts them by email or phone. About 40% of students new to the Emporium have gone in after being contacted.
- A "Foundations lab" to support students in pre-college level math classes. The center targeted 6 sections of Pre-Calculus for embedded tutoring: targeted students had a 59% success rate, while others not targeted had a 44% success rate.
- "Test corrections" mastery instruction system: Students can recover lost points on an exam. They must orally defend their new answers, as well as explain previous answers. Instructors say that "through this process students develop deeper understanding and confidence in the subject and in their answers."
- Acceleration program: a summer bridge program to help students start college with credit for a higher math course, and so have a greater chance to persist and graduate. In two sessions, 70% of students (out of 130) increased one level or higher.
- The Emporium maintains worksheets for students covering course subjects.
- Peer-tutoring: Expanded to cover new subjects.
- Integrated Emporium activities into Math 1A classes: created Readiness testing and booster/scaffolding activities with Math 1A faculty, and added Workshops for Math 1A.
- Feedback to and from instructors, to improve teaching and Emporium offerings: the center added a computer science workshop on algorithms and data structures based on instructor feedback.
- Practice sessions with faculty on best practices in providing support: Role-play effective tutoring strategies, test corrections, and supporting a growth mindset. Instructors have

given very positive responses.

- Coordinating with the "Teaching and Learning Center" for integrated and consistent services: the two centers have collaborated on recruiting, staffing, using and improving the SARS system to track students, and on the campus embedded tutoring program.
- Diversification in professionals: Hired two minority instructors in subjects that previously had none. One reported that "it made a difference for Math 105 students who were happy to see a Hispanic instructor in the center."
- Internal Advisory Committee (IAC): The department's advisory board has made improvements to the test corrections process, has obtained resources from instructors to support workshops, and has redesigned a workshop based on instructor suggestions.

Results: Provide STEMWay Internships

Goal: Provide STEMWay Internships. *Benchmarks:*

Year 2 start: Begin STEMWay internships.

Internship programs were made available at Foothill College in 2013-14, including research internships at Stanford University, University of California Santa Cruz Advanced Systems Laboratory, San Jose State University, and San Jose Technical Museum. An internship building block was installed in the math LMS in Fall 2013, and will also be provided in the interim Etudes LMS in Fall 2014, along with Foothill College's own internship department.

Results: Evaluation and Dissemination

Goal: Evaluate STEMWay quantitatively. Disseminate outcomes and consequences.
Indicators:

Year 1 Month 9: Quantitative evaluation of STEMWay effect on student success for year 1.
Year 2 Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-2.

In Year-1, the college Researcher Elaine Kuo gathered data on math courses and students, and usage of the Emporium. The Foothill College Internal Advisory Committee (IAC) gave feedback and recommendations on improvements. At the end of Year-2, External Evaluator Robert London was brought in to conduct an independent evaluation, summarized in this document.

Conclusions: Year-2 Summary

At the end of its second year, despite a schedule-shaking late start to funding and two serious difficulties, the STEMWay project has had strong success in all of its main goals. The primary purpose of the project has been to show and validate an approach to improving the rate of student success in associate-degree level STEM subjects, starting with math. The STEMWay approach is to provide complete out-of-classroom support for students, backed by collaborative faculty, technology, community, and tutoring. The project had one unforeseeable disaster in the sudden loss of its technical/analytical Co-PI, Ion Georgiou, and hit one major and one minor snag in its plan. The main technical approach was to apply and adapt a programmable LMS, selected to be Blackboard, but that tool proved to be too limited in offerings, in flexibility, and in adaptability. Though a better solution is forthcoming – the California Online Education Initiative, with which STEMWay PI Silverman will collaborate – the answer is unlikely to be ready in the time-frame of the STEMWay grant. Instead, an assortment of software tools will be used along with Etudes, a basic LMS. A related challenge has been implementation of a strong readiness

assessment suite, which was planned to be part of the programmable LMS. This will be the focus in the next year for Foothill College Math Instructor Zachary Cembellin.

Nevertheless, the other services through the STEMWay Emporium have more than compensated for those difficulties. The most popular and successful Emporium offerings have been sets of workshops that cover the project's booster/scaffolding approach to full-coverage instruction; tutors largely from nearby universities; and scheduled instructor mentoring. Other services have also been added and have shown both popularity and educational promise: a "Foundations Lab" to cover pre-requisite subjects; an "Early Alert" in association with course instructors to tutor students proactively; a "Test Corrections" program to give students a second chance as well as to deepen their understanding; an "Acceleration" program to help lift students toward graduation optimally; peer-tutoring, class-embedded services, along with others.

Data gathered by Foothill Researcher Elaine Kuo consistently indicates (though does not yet prove) instructional value of STEMWay Emporium services leading to improved graduation rates; remarkably, the early Year-2 graduation increases are very close to the projections in the project proposal. Given the very slow start to the project, if those trends continue then increases in graduation rates may considerably outdo the proposal's goals. Considering that STEMWay is missing two of the key ingredients in the proposal's model – a programmable LMS and a strong readiness assessment suite – the project appears to have a winning combination that covers missing pieces with a critical mass of alternative services.

From reviewing those services and their results, STEMWay's key ingredient for success to this point appears to be one that was barely mentioned in the proposal and just occasionally in the project's Annual Reports: collaboration. Both Project PI Silverman and Emporium Director Reed pursue and emphasize collaborating with course instructors, with tutors (both external and embedded), with student peers, and with advisors. PI Silverman is currently working to extend that collaboration to a staff-wide model of "Growth Mindset," promoting a persistence approach to learning. Director Reed also is extending collaboration beyond the STEM department into other sections of the college, including language learning. Even after just two years, this approach has led to highly active tutoring, mentoring, class-embedded remedial services, and faculty/Emporium feedback leading to improvement on both sides. While implementation of a diagnostic LMS and an accurate readiness assessment tool would be valuable (and still might be), the suite of collaborative methods being formed in STEMWay appears to be possibly even more valuable, and still has a great deal of room for improvement and additions in the coming three years.

Recommendations

The main recommendation is simple and obvious: to continue along the current successful path, which in less than two years has achieved more acceptance, popularity, and educational gain than proposed, and all that despite difficulties that would cripple most projects. The key point of the project's proposal – total coverage of supplemental instructional services – is working well, in some instances so well that the Emporium is filled past capacity. Then collaboration across all groups is the unemphasized ingredient that seems to be getting all the services to work well together. This report and the Annual Report have mentioned several directions that can particularly use further work and improvement. In this kind of multi-complementary, full-coverage approach, nearly every service and direction can take further attention and improvement. Still, following are a few specific recommendations:

- In recruiting students into the Emporium/PSEC, follow up with survey responders (or

continue with another survey) on stated answers of “Why don't you use the PSME Center?”; though some are obvious and some probably flippant, they may lead to helpful improvements. (“Not open when I need it; Takes too long to get help; Crowded / Noisy; Need food; Not designed for me; Instructors don't know my subject”)

- The stated intention to focus on recruiting domestic students to use the Emporium may not be so crucial; though domestic students have started with considerably lower success rates than visa students, the early project data suggests that both groups are growing at about the same rates in usage of the Emporium and in course success when they use the Emporium, and so specialized recruiting may not be necessary after another couple of years of improving Emporium offerings.
- Physical size of the Emporium/PSEC: "bursting at the seams, especially mid-quarter”; consider adding distributed, satellite PSEC spots for limited activities like tutoring, mini-workshops, practice sessions.
- Continue building on collaborations, feedback, and cross-category communications, as the project has been doing.

Appendix H:
Additional Materials on Section 12: Evaluation — Target Outcomes

STEMWay Evaluation: Formative and Summative

The primary goal of STEMWay is to substantially increase the number of STEM student graduations: associate degrees and transfers to baccalaureate STEM programs. The 5-year project goal is to increase Foothill College's college-math graduation rate by 95%, to 26% in 2017. The project approach is to improve the potential for success of all STEM students – and especially for midrange (C and low-B) students – by centralized tracking, continuous interventions, and personal mentoring; thereby increasing student retention, graduation rates, and transfers to 4-year STEM programs. Total results will be assessed, as well as each method as an independent factor, for both formative and summative recommendations, by the project external evaluator, Dr Robert London, an educator with formal training in educational evaluation. Dr London will provide an evaluation report to the project leaders, the Internal Advisory Committee, and to the NSF in annual and interim reports.

A formative evaluation plan will assess the ongoing success of the STEMWay program components, while maximizing the opportunity for success by continuous feedback and recommendations to project leaders, who can then make adjustments for re-evaluation. Emporium data of student progress will be sent for analysis to the project evaluator. For close tracking and timely analysis, STEMWay will set baseline measures at the start of the program, and a quantitative progress plan for analysis of expectations versus results. Expected pathways, progress rates, and key juncture points will be mapped from historical data plus definitions for course SLOs (student learning outcomes) and pre-requisites.

The primary program goals, to significantly increase math graduations at the 2-year college and to further increase baccalaureate STEM graduations, will be measured in coordination with the project's student trackers. This will require definition of a longitudinal model of alternative student pathways. Also, more fine-grained measures will be assessed for course success (course grades + intermediate results to measure mastery of SLOs), and student retention (follow-up courses or program results). To analyze separate factors, STEMWay evaluation will include quantitative analysis of program success rate factored by resource utilization, program component cost-effectiveness, and student demographics including ethnicity and gender.

STEMWay emporium usage and efficiency data will be analyzed for preliminary indicators of program success as well as for continual improvement of the program's methods. Emporium usage indicators include the number of hours of student usage, module assessment scores, number of tries for each module, and student survey feedback. These will be analyzed against intensive pilot program data to monitor success of the program and its methods.

For all students in each pathway course, evaluation will continually track data related to course entry (based on readiness tests plus sequence course grades) and STEMWay usage (instructor recommendations, accesses, completions, student feedback). For each pathway course tracked in STEMWay, evaluation will gather data on prerequisites, readiness tests, SLOs, booster modules, instructor usage of STEMWay, STEMWay materials applied, and student survey responses. Student usage of the emporium will be correlated with course results.

Qualitative data will also be analyzed. STEMWay will be administering feedback and follow-up surveys to all students. Dr London will coordinate with STEMWay staff to analyze student surveys and also to administer surveys to project faculty, advisors, mentors, and counselors, to analyze the most specific recommendations for program modifications. For detailed qualitative data and analysis for developmental recommendations, Dr London may also act as a participant-observer, in the role of instructor aide.

The resulting evaluation of STEMWay will be a detailed recommendation regarding expansion of STEMWay into additional STEM subjects, with continued improvement and self-sustainment by integration as a permanent Foothill College program. In addition, analysis will produce a summative evaluation of STEMWay as an empirical, quasi-experimental test of Seidman's retention formula for student success, with effectiveness of program strategies, instructional materials, and resource management included as independent factors.

Benchmarks

Key Project Benchmarks (Milestones):

(Italicized milestones are planned extensions and are not part of the funded project budget. Benchmarks also include annual reports on STEMWay progress, with modification plans.)

Year 1 start: Emporium readiness testing, booster/scaffolding active for 1 calculus course.
Begin faculty training for use of STEMWay. Mentors active in emporium.
Month 4: Emporium readiness testing, booster/scaffolding active for 2 calculus courses.
Month 9: Emporium readiness testing, booster/scaffolding active for 3 calculus courses.
Quantitative evaluation of STEMWay effect on student success for year 1.
Year 2 start: Emporium readiness testing, booster/scaffolding for 3 calculus courses.
Begin STEMWay internships.
Month 9: Emporium readiness, booster/scaffolding for 3 calculus
Quantitative evaluation of STEMWay effect on student success for years 1 and 2.
Year 3 start: *Emporium readiness testing, booster/scaffolding for chemistry courses.*
Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-3.
Dissemination of mid-project outcomes.
Year 4 start: *Emporium readiness testing, booster/scaffolding for physics courses.*
Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-4.
Year 5 start: *Emporium readiness testing, booster/scaffolding for computer science courses.*
Month 9: Quantitative evaluation of STEMWay effect on student success for years 1-5.
Dissemination of project outcomes; report on success of STEMWay project (15 terms + modification plans), including recommendations for national usage of results.

Indicators

Key Project Indicators (End-of-Year Targets and Checkpoints):

Year 1: Target emporium usage (% of key STEM course enrollment):* 10%
** Number of students using emporium at least 12 hours per term*
Target math graduation: increase 5% to 14%, from projected baseline of 125 to 132
Year 2: Target STEM course enrollment increase: 5%; emporium usage: 20%
Target math graduation: increase 32%** to 17.5%, from projected baseline of 128 to 172
*** Increased rate applies to projected increase in number of entering students*
Year 3: Target STEM course enrollment increase: 7%; emporium usage: 30%
Target math graduation: increase 69% to 22.5%, from projected baseline of 135 to 237

Year 4: Target STEM course enrollment increase: 9%; emporium usage: 40%
Target math graduation: increase 88% to 25%, from projected baseline of 141 to 288
Year 5: Target STEM course enrollment increase: 10.5%; emporium usage: 50%
Target math graduation: increase 95% to 26%, from projected baseline of 149 to 331

Summary of Metrics

	Number of Majors	Expected Number of Majors for Disciplines Involved in the Project										Expected Number (end of funding)	
	Fall Prior to Funding	Year 1		Year 2		Year 3		Year 4		Year 5		**Total**	
	Lead Institution	N	%	N	%	N	%	N	%	N	%	**N**	**%**
Math	**940**	**940**	**0%**	**987**	**5%**	**1056**	**7%**	**1151**	**9%**	**1272**	**11%**	**5406**	**15%**

**Fall 2011 headcount in Math 1A/B/C/D, Math 2A/B, Math 49 is 990.*

Proposed increases expected in the annual numbers and percentages of STEM students transferring from a 2-year institution to a 4-year program during the 5 years of the project

	# Transfer Students	Expected Number of Transfer Students for Disciplines Involved in Project										(end of funding)	
	Fall Prior to Funding	Year 1		Year 2		Year 3		Year 4		Year 5		**Total**	
	Lead Institution	N	%	N	%	N	%	N	%	N	%	**N**	**%**
Math	**125**	**132**	**13%**	**172**	**30%**	**237**	**38%**	**288**	**22%**	**331**	**15%**	**1160**	**86%**

STEMWay Project Summary

The main goal of STEMWay is to increase the number of STEM graduates, with focus on underrepresented students. STEMWay's goals are to empirically test a comprehensive longitudinal model of student success in STEM progressions for community colleges and to examine the impact of using smart management strategies, given the limited resources that exist at community colleges. STEMWay will achieve this by first increasing math pathway completion through improving course placement for students, monitoring and continually aiding students' coursework mastery, and mentoring students' pathway progress.

STEMWay's emporium methods include readiness testing for course readiness, booster modules to accelerate students to a course or unit's requisite skill level, and scaffolding to support students through parts of a course where a student may have knowledge holes. A key to success in STEM student retention will be effective integrating management of comprehensive academic support services to those students that are most at need. STEMWay targets an increase in math program graduation by 95% in 5 years, to 26% in 2017, to be followed by expansion of STEMWay academic support to remaining STEM subject areas.

Intellectual Merit

STEMWay is a testable model of "powerful intervention," a theory of student retention that has been proposed but not yet fully implemented, according to its chief theorists Tinto and Seidman. STEMWay combines early and continuous assessment and intervention with strategic management optimization practices, and with academic community construction. STEMWay methods will produce improved pedagogical models and strategies for STEM success. The experiences of the full program and of each of its parts will inform colleges in best practices for STEM student retention.

STEMWay defines and applies a system of wrap-around services for students' academic needs outside the classroom. STEMWay adapts many external resources for assessment, placement, and scaffolding. The combination into a comprehensive solution for complemen-

tary academic support with longitudinal implementation, and applied management science to add adaptive allocation of resources, is new.

Principal Investigator Loretta (Lori) Silverman and Co-PI's Ion Georgiou and Peter Murray are highly suited for this research challenge. Dr Silverman and Dr Georgiou are accomplished, tenured math instructors and have already implemented several of the emporium methods. Lori was the first coordinator for Foothill College's program in College Skills, where she inaugurated the Basic Skills Initiative, including professional development workshops and assessed learning center for students. She also managed the Foothill Math Center, where she supervised up to 25 faculty and 10 graduate students in a campus facility providing students help with assigned homework and tutoring on unfamiliar math concepts. Lori specializes in community college student retention; her recent PhD dissertation was on student retention,[1] advised by Dr Alan Seidman, a distinguished leader in the field of college student retention.

In addition to expertise in curriculum development and instruction, Dr Georgiou adds experience in management science (having managed software companies developing performance metrics) and research programs (consulting in development of theoretical and computational tools and in physics). Peter Murray has been Co-PI on the NSF STEP grant for "Developing Effective Engineering Pathways;" he received the President's Award for creating the basic skills math course "Math My Way," and created the first California accepted program in nanotechnology. The core team of Silverman, Georgiou, and Murray are ideally suited to design and operationalize a multi-service facility to combine best practices of student evaluation, targeted tutoring, and mentoring for optimal retention and program completion.

[1] Silverman, Loretta H. (2010).