**Nanoscience Program - Plans to Increase Enrollment - October 11, 2015**

Since the beginning of the nanoscience program in 2004, through the NSF funding (2009-2013), and to date (fall 2015), the nanoscience program hasn't grown in enrollments as expected and hoped for. Through the NSF funded five course certificate program (NANO 50, 51, 52, 53, and 54) were developed.

NANO 50 - Nanoscience
NANO 51 - Nanotechnology Applications
NANO 52 - Nanostructures and Nanomaterials
NANO 53 - Nanocharacterization Tools and Methods
NANO 54 - Nanofabrication Tools and Process

From 2009 - 2013, the program saw the following enrollments (completions)

NANO 50 - 12 students
NANO 51 - 35 students
NANO 52 - 30 students
NANO 53 - 19 students
NANO 54 - 20 students

NANO 52-53-54 20 students

In the first cohort - a dozen students completed the full certificate (2009-13) in the two years since then, eight students have attempted the whole sequence, and roughly six have or will soon complete the four course sequence. Thirty students have completed two or more of the advanced classes (NANO 52-53-54). Roughly half a dozen experienced an increase in job responsibilities as a result of the program, five-six have transferred into engineering programs, of which three (or four) have completed a four year degree, and two are in progress. Three students have also gained full-time employment in characterization / fabrication / process development, and all in the last two years.

Since 2013, a total of (35 students) have attended/completed NANO 51, 32 students in NANO 52, 29 students in NANO 53, and 26 students in NANO 54. Currently 7 students are enrolled in NANO 51, and 16 students in NANO 53. Of this "cohort", ~15 also completed NANO 52, Nanostructures. ~13 completed NANO 52 and NANO 53 (Nanocharacterization), and ~ 10 completed the three advanced courses (NANO 52-53-54) and additionally NANO 51 (Nanotechnology Applications). Of 11 students that could have completed all four course, two failed to complete (or have not yet completed) NANO 53. So, since the first cohort completed all four courses in the certificate program, and additional 10 students have or will be ready to complete the four course certificate (or at least the three advanced courses). A trend that was observed in the second year of the certificate program, half of students who enter the program do not start with NANO 51 (Nanotechnology Applications) and instead enter an advanced course (NANO 52-53-54). Of all the advanced courses, NANO 52 (Nanostructures) is the most popular.

In fall 2014 Foothill College offered NANO 10, Nanoscience, at Palo Alto High School, with a total of 18 students completing the semester, with 13 students enrolled there in fall semester 2015 (12 students expected to finish). In spring semester 2015 a total of 10 students attended an after school NANO 10 course, ran as a "club" with short lectures, activities, and take-home assignments.

Challenges to enrollment

Since the beginning of the program it's been difficult to build enrollment past 15 in any of the classes, with typically a dozen students completing the courses. Over half the students enroll in an advanced course simply wanting to learn about nanotechnology, and it's difficult to master the advanced material without a basic foundation (NANO 51). That said, many of these students will go on to take one more advanced course. Given a typical year, roughly 25 unique students will take at least one course in the nanoscience program.

NANO 10 - Nanoscience - was taught at Palo Alto High School for the first time in fall 2014, with ~ 18 students completing the first cohort (two sections were taught). This course included both labs and demonstrations, and students received both high school and college credit. In spring 2015, NANO 10 was taught at Gunn High School as an after school course, more like a science club with short lectures, demonstrations, weekly assignments, and take-home exams. Nine students completed that course. In fall 2015, 15 students enrolled in NANO 10 at Palo Alto High School, with current enrollment (and expected completions) of ~13. The course is being offered in a deliberately less stressful mode for these students, with lab activities and demonstrations representing ~ 50% of the course, with a goal of nearly 75% by fall 2016. As described later, we are entertaining a revision of the high school NANO 10 course to follow NGSS (Next Generation Science Standards) in a format that is "extensible" across the US (funding permitting). Additionally, we are considering bringing NANO 10 to Foothill as a lecture-laboratory course (integrated hands-on demonstrations).

NANO Camp (STEM camp)

In July 2014 STEM Camp provided two weeks of NANO Camp in which ~ 25 individual experiments and demonstrations were conducted for a total of ~ 40 students. Building on the experiments conducted in NANO 10 (PAUSD) in fall 2014 to spring 2015, NANO Camp 2015 hosted six cohorts ( 3 weeks of half-days) with 120 students completing the camp. Experiments and demonstrations included more difficult labs run in NANO 10. It's clear that there's interest in high school students to participate in a "fun" approach to investigating nanoscience and nanomaterials. As mentioned above, the high school version of NANO 10 is more on the "fun side" of a college course, resembling a high school elective. We'll continue to develop more sophisticated labs in NANO 10 that can be used in NANO Camp, and vice versa. Assistance from the chemistry stockroom staff has been pivotal in getting the more difficult labs / demonstrations to work properly.

Saturday Microscopy lab - as an addendum to all courses, the microscopy lab is open Saturday morning for all Foothill College students but especially Nanoscience program students. We meet from 10ish to 1 p.m., and occasionally do small laboratory demonstrations (lab prep and development) during this time.

Plans for a revised program:

NANO 10 (lecture laboratory course) - Foothill lacks a formal laboratory science class in nanoscience, and NANO 10 is headed towards being a very hands-on course, and does include formal laboratory experiments and write-ups. The course outline of record is slightly more rigorous than as run in high school, per the method of delivering an elective in a fun learning environment. NANO 10, like many of the AP / tracked courses in high school, can be run in "two speeds" that recognizes the relative ability of high school students to take on new and challenging vocabulary. Creating a laboratory nanoscience course at Foothill would also provide a new science option for many transferring students, and additionally activities in a lecture class create a more effective learning outcome. Towards that goal, NANO 51 taught in fall quarter 2015 will include at least one hands on activity each week.

NANO 51 would stay as the primary survey course for nanoscience and nanotechnology, with an evening offering for the general community. It might be an effective course to move to the new Foothill College Sunnyvale Campus, with the ability to draw from Mission West Valley and De Anza College, offering their students an opportunity to learn about nanoscience. A concern that we've had with nanoscience from the beginning is that Foothill College is too small of a college to really draw enough interest and enrollment for this program, and that a college, De Anza for instance, might be a better fit to generate enrollment. NANO 51 doesn't have a laboratory component, so it could work with a seminar only venue like the new campus.

NANO 62 - a hybrid capable course, was approved by the curriculum committee as a melding of the three advanced courses, NANO 52-53-54, with nanostructures as a central focus, integrating structure - properties (NANO 52), Nanocharacterization (NANO 53) and Nanofabrication (NANO 54). This course would assist students who have completed the survey course, and want to have a "deeper dive" into nanostructures, fundamental structure => properties relationships, and how to fabricate and characterize, which is the fundamental PNPA pedagogy. NANO 62 would be targeted to advanced students and working professionals that want to understand nanomaterials from an integrated engineering perspective. This single course will replace the NANO 52-53-54 series, and provide the ability, through extended course material, for students to continue to learn about nanomaterials after the course ends.

Microscopy lab and NASA internships - Foothill College has a microscopy lab in PSEC building room 4705B with a tabletop Scanning Electron Microscope (SEM), and an Atomic Force Microscope (AFM). These instruments are available to nanoscience program students on Saturday morning and immediately before evening classes. These instruments provide students with the ability to study nanomaterials, as well as conduct independent research. NASA-ASL (Advanced Studies Lab) also provides opportunities for students to participate in materials engineering research through the MACS

(Materials Analysis for Collaborative Science) facility, which includes access to a carbon furnace, Field Emission Electron Microscopes (FE-SEM), and Transmission Electron Microscopes (TEM). Training has been available through Perkins workforce funding.

The key ideas in the program enrollment plan are:

1. NANO 10 (Nanoscience) as an activity / laboratory course (PAUSD and Foothill)
2. NANO 51 (Nanotechnology) transition to a regional campus (Sunnyvale Center)
3. NANO 62 (Nanomaterials Engineering) as an integrated advanced course replacing 52-53-54
4. NASA-ASL and MACS facility for advanced training in microscopy
5. NANO 10 (High School) and NANO Camp for high school outreach

Additional areas of outreach include being active in the engineering clubs at both Foothill and De Anza College. The sabbatical plan to increase FHDA student present at NASA-Ames, and to assist NASA's educational outreach through the Sunnyvale Campus, may enhance NANO program exposure. Robert Cormia will be working with De Anza College students in fall 2015 and winter 2016 to increase the number of students working in the ICG (Innovation and Collaboration Group) which draws students from both FHDA campuses, with potential internships at NASA-ASL.

A revamp of the program focuses on providing a laboratory like course (NANO 10) for students at Foothill College, a survey course for students interested in what nanoscience is about (NANO 51), and an advanced course that integrates material structures, properties, fabrication, and characterization (NANO 62). This "integrated materials engineering method" follows real world advanced materials development, as well as the integrated PNPA pedagogy used to develop the NSF funded nanoscience program (DUE 0903316).

NANO 10 is in a state of continual development, adding hands-on activities for both Palo Alto High School (PAHS) and Gunn High School (PAUSD), and over a planned sabbatical in fall 2016 would add NGSS (Next Generation Science Standards) into both lecture and laboratory activities. Assistance in teaching the course over sabbatical might be provided from a chemistry faculty at PAUSD, who also has worked with NGSS integration in high school chemistry curriculum. Enhancing NANO 10 laboratory activities is the necessary step in preparing the course for Foothill.

NANO 62 can be developed from material already in use in NANO 52 (Nanomaterials and Nanostructures), approximately half the course would need to be modified, largely by integrating material from NANO 53 (Nanocharacterization Tools and Methods) and NANO 54 (Nanofabrication Tools and Process). This process has already begun, and will get more attention in winter 2016, in preparation for NANO 52 being offered in spring 2016. Given that enrollments in the NANO 53 are stronger this fall, largely through coordination with SJSU, a goal of ramping NANO 52 from low to mid-teens to high teens and low twenties for NANO 62, may be a reasonable target enrollment.

The real key to growing enrollment for the program will likely come from recruiting students from Mission West Valley and De Anza College, through the new Foothill College Sunnyvale Campus, and its workforce program emphasis. Integral to this is stronger coordination with NASA-ASL projects and internships, and especially the pathway from the ICG (Innovation and Collaboration Group) clubs at Foothill and De Anza to NASA-ASLs ICG (science and engineering laboratory). These ICG club => ASL internship activities are beginning in earnest in fall 2015 and winter 2016.

NANO Certificate Program

The NANO certificate program will be impacted by these changes; we are condensing three advanced courses into one, bringing in a new course (NANO 10), and slightly repositioning the survey course as a recommendation for the advanced courses, and bringing it into a regional workforce center. The one course that is missing from this sequence is a hands-on laboratory course in microscopy, which was submitted twice to curriculum committee, and turned down as SJSU teaches similar (but separate) courses in Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). The addition of a hands-on laboratory course for a short certificate program would add a needed dimension to the program. Perhaps the Program Review Committee could work with Curriculum Committee to see if there is a way to formalize our Saturday morning microscopy course into a weekday (morning or afternoon) hands-on course that would combined directed and independent study activities.

Summary:

NANO 10 (Nanoscience) - Develop an on-campus laboratory course with enhanced activities and outcomes.

NANO 51 (Nanotechnology) – revisit the survey content to ensure it meets workforce needs. Formalize Saturday lab.

NANO 62 (Nanomaterials Engineering) – combine NANO 52 (Nanomaterials and Structures), NANO 53 (Nanocharacterization), NANO 54 (Nanofabrication) into a PNPA centric pedagogy (integrated materials engineering method)

Microscopy tools – offer an informal certificate for completion of a basic microscopy curriculum. Some students may be able to operate the more advanced equipment at NASA-ASL (Advanced Studies Lab)

Timeline: NANO 10 is in continual development, with a major effort planned from July 1 to December 31$^{st}$. This will coincide with a planned PDL and fall semester offering at Palo Alto High School. NANO 51 will be revisited for workforce applications during winter 2017 (proposed PDL) NANO 62 is being developed (slowly) during winter quarter 2016 with some trial lectures planned for spring 2016 (NANO 52). The microscopy class is a “work in progress” every Saturday morning, with a small handbook planned for winter 2016. Progress with the curriculum committee is needed for formal development. Coordination/discussions with the Sunnyvale education center has already begun (on an informal basis).