ERC BEST PRACTICES MANUAL
CHAPTER 4: EDUCATION PROGRAMS

4.3 PRECOLLEGE AND COMMUNITY ENGAGEMENT

4.3.1 Purposes and Goals

ERCs have a mandate to contribute to the precollegiate education system by introducing young students and their educators to the field of engineering and the technology impacted by the center's interdisciplinary research. The purpose is to bring knowledge of engineering to middle and high schools where the emphasis is on science education, with little understanding of the field of engineering. Additionally, there is a significant lag in textbook production, so an effort to integrate center research into classrooms brings cutting-edge engineering content to students in a timely manner. ERC K–12 programs are focused on helping to encourage students to consider careers in engineering. Given the limited ERC budget, when compared to the total precollegiate education system, ERCs and NSF recognize the limits of the impact they can have and that they cannot be all things to all constituencies. It is critical therefore that each ERC determine what precollege offerings work in the context of its specific strategic plan, resources, and community relationships.

Precollege education programs can increase student awareness of engineering careers and stimulate student interest in pursuing them. A key element to all ERC precollege programming is the recognition that it is in the national interest to encourage students who are traditionally underrepresented in engineering and technology careers to become involved. Focusing on underserved populations can contribute to efforts to increase the diversity of domestic students studying engineering at the college level.

ERC precollege programs cannot succeed without partnerships with local school districts and/or individual schools. A strong relationship with these partners will create (1) STEM teachers' involvement in ERC research and education programs; (2) creation of engineering-oriented educational modules for their school teaching activities and for integration into their curricula; and (3) strong impact on diversity and broadening participation of underrepresented groups, teachers, and students into these engineering experiences. See examples of such partnerships in appendix 4.3, section 4.3.7.

Some best practices for achieving successful precollege outreach are as follows:

- To make the best use of limited resources for ERCs' precollege outreach, many ERCs work in partnership with other education and outreach programs. For maximum impact, it is best to seek out established programs to which ERCs can add significant value, or to find promising new endeavors with which to partner. Partnerships may include university programs; school and school system organizations; and/or community resources, including informal science centers and public libraries.
- Another key feature of successful programs is the involvement of graduate and undergraduate students as well as the ERC's Student Leadership Councils (SLCs) in activities. These may include school visits and student tours, as teacher or student research mentors. Secondary school students often relate well to university students, who are closer to their own age. Engaging graduate students in outreach enhances their communication and leadership skills.
- To encourage program diversity, it is useful to partner with established campus multicultural programs; for example, ERCs have partnered with chapters of the National Society of Black Engineers (NSBE), the American Indian Science and Engineering Society (AISES), and the Society for Women Engineers (SWE). Additional partners include women in engineering programs and minority/multicultural engineering programs.
- Successful outreach programs are led by teams involving university educators and education faculty, precollege STEM teachers, as well as center engineers and researchers. Each group offers different talents and specialties that contribute to outstanding programs.

- It is best to have an educator with experience in K-12 education responsible for the pre-college program at each participating ERC location. Programs can be administered from a central location, but an on-site educational leader on each campus is desirable. Forming an Education Committee or Thrust with a representative from each campus can be valuable in accomplishing this goal.

The programs described below are for both K–12 students and their teachers. They include the two that are required for all centers, Young Scholar programs (Gen-3 only), and summer Research Experiences for Teachers (RET). In addition to these required programs, centers have developed other programs such as summer camps, courses, internships, science and engineering competitions, lab tours, school visits, lectures, and science and education fairs, some of which are conducted on-campus at the ERC and others on-site at the partnering school(s).

Given the creativity of center precollege personnel at developing innovative student opportunities, and the resulting variability of programs developed, the best way to understand the range of possible offerings is to review the examples that are found in Appendix 4.3 to this section. Contact information is provided and existing center administrators will be happy to share details about any programs that they have developed. All of these programs require significant time and resources to develop and administer. It is important for the center's strategic plan to include timetables that plan for the gradual phased implementation of Education programming over time rather than attempting to bring all these types of effort up to speed in year 1.

4.3.2 Required Precollege Student Engagement

Young Scholars Program (Gen-3 only)

Generation-3 ERCs are required to develop and to offer a Young Scholars (YS) Program to provide opportunities to exemplar high school-age students to participate in ERC summer research programs or internships. The purpose is to get students into research labs early in their careers, in order to excite and interest them in pursuing research and in engineering careers. These programs can require significant effort from administrative and research staff. They generally involve center graduate students who serve as mentors to the students. Please note: there may be existing programs on campus that also serve these students that the ERC can leverage. (See example 4.3.4.1 and section 4.3.11 in Appendix 4.3.)

Student Competitions

Some ERCs sponsor student technology competitions or science fairs. Often, this is done by involving center researchers and graduate students as well as local partner organizations. The purpose is to involve students early on in their academic preparation in exciting engineering and science projects and research, or in fairs and exhibits displaying interesting and topical research.

> **FEATURED EXAMPLE:** *The graduated ERC for Computer-Integrated Surgical Systems and Technology sponsors a semiannual robotics competition for local high school students. The CISSRS LEGO Robot Competition is a weekend-long competition giving high school students hands-on education and experience in engineering problem solving. The students, working in teams, design, build, and program a robot to perform a simulated surgical procedure.*

See example 4.4.6.1 in Appendix 4.4 for an international competition involving undergraduates as well as high school students. Example 4.3.4.5 describes ERC faculty involvement in a science fair that led to a high school student conducting research at the ERC.

Student Camps and Courses

Many ERCs have sponsored student camps and courses to involve K–12 students in fun, hands-on science and engineering experiences and thereby interest them in technology and careers inengineering. ERCs may also integrate center research into existing camps as a way to introduce broader audiences to engineering and science. See examples 4.3.4.2, 4.3.4.3, 4.3.4.4, 4.3.5.1, and 4.3.13.1 in appendix 4.3. Field trips and tours of ERC labs are another way to engage young students' interest. See 4.3.12.1, for an

example.

In many cases, ERC students go to precollege schools, even at the middle school and elementary school level, to bring fun demonstrations to classes in order to engage young students in engineering concepts. See example 4.3.5.2 and 4.3.6.1.

4.3.3 Precollege Teacher Engagement

Research Experiences for Teachers (RET)

One of the fundamental components of ERC precollege education is the Research Experiences for Teachers (RET) program. The purpose of the RET program is to excite K-12 teachers about engineering by providing them with knowledge of cutting-edge research. Effective programs engage K-12 teachers in developing and modifying lessons to incorporate concepts learned during their research experiences. Graduate student researchers will need to be heavily involved, as they will serve as mentors to these participants. The most effective programs have students who accompany their teachers to campus during the summer and have outreach to the teachers' classrooms during the academic year by teams of faculty and students from the ERC.

See examples in appendix sections 4.3.2 and 4.3.3. Examples of precollege outreach programs that encourage greater diversity among engineering students are in appendix sec. 4.3.10.

Development of Instructional Materials

In addition to K-12 teacher-developed curricular materials, several ERCs have developed curricular materials for K-12 teachers that are based on the center's research. If it is determined that the production of classroom materials is part of the strategic plan, it will require a development team that includes members of the targeted school district, classroom teachers from the targeted grade level, and center personnel. Partnerships with Colleges of Education and the engagement of Education students may also extend these efforts. It is important that educational materials reflect all local, state and national standards and are developmentally appropriate. For example, some states require application of Next Generation Science Standards (NGSS) and the new engineering standards within them. Education Directors should consult the standards that apply in their area.

> **FEATURED EXAMPLE:** *The NSF Nanosystems Engineering Research Center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) has partnered with professors of STEM education and engineers and has created nanoscale investigations that are correlated with science standards. The investigations are teacher-tested and reviewed by scientists and engineers as well as STEM researchers.*

For additional examples in the appendix, see 4.3.1.1, 4.3.4.3, 4.3.6.2, 4.3.8.1, 4.3.11.3, 4.3.11.5, 4.3.13.1, 4.3.14.1, and 4.3.14.2.

Conferences and Workshops

Some ERCs offer K-12 teacher professional development conferences and workshops. Professional development for teachers allows ERCs to multiply their efforts and to reach more K-12 students by increasing teacher interest and knowledge in science and engineering, particularly in exciting new research. Organizing these conferences can also require significant amounts of administrative and research staff effort. Participating in an existing conference requires less effort. For example, the NSF Nanosystems Engineering Research center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) provides professional development to K-12 teachers through on-site workshops as well as sessions for teachers at national and state teachers conferences.

> **FEATURED EXAMPLE:** *The ASSIST NERC provides professional development to teachers through on site workshops as well as sessions for teachers at national and state teachers conferences.*

For additional examples, see appendix 4.3.3.1, 4.3.6.2, 4.3.7.3, and 4.3.14.1.

4.3.4 Community Engagement

Public events such as Science Cafés and science center presentations are effective ways to share research with adults and families in local communities. These types of outreach efforts build support for the ERC and for research. Such opportunities to participate in ongoing outreach efforts can be easy ways for ERCs to reach out to communities. See examples 4.3.6.2, 4.3.9.1, 4.3.9.2, 4.3.9.3, 4.3.9.4, 4.3.14.1, and 4.3.14.3 in Appendix 4.3.

To better engage veterans in engineering projects, NSF is now accepting requests from their active grantees for the Veterans Research Supplement (VRS)[1]. The proposed VRS will afford veteran students, veteran precollege teachers, or veteran community college faculty an opportunity to participate with active ERC grantees to conduct industrially relevant research in order to gain a deeper understanding of engineering.

4.3.5 Precollege Education Lessons Learned

To be effective, precollege outreach requires professional leadership and substantial resources. Furthermore, the outreach program should be included as a key component of the center and the Precollege Director should be included as part of the center's Leadership Team.

Center Directors should schedule regular times to meet with precollege personnel and promote inclusion of the precollege program in center activities.

In order to promote and sustain a more diverse engineering workforce, the center should strive to create an inclusive and supportive work environment for precollege teachers and students.

[1] See Dear Colleague Letter Number NSF 13-047.

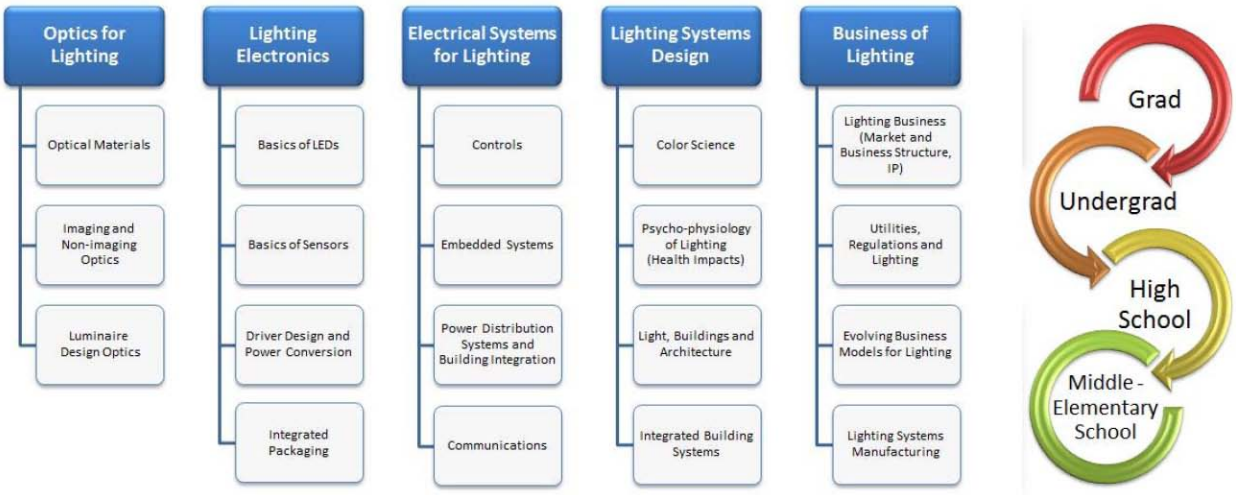
APPENDIX 4.3
PRECOLLEGE AND COMMUNITY ENGAGEMENT EXAMPLES

4.3.1 Precollege Program Planning

4.3.1.1 ***Center:*** Smart Lighting ERC
Lead Institution: Rensselaer Polytechnic Institute
Center Director: Prof. Robert F. Karlicek, Jr., Dept. of Electrical, Computer, and Systems Engineering
Name of Program: Illumineer Curriculum with Mentoring Hierarchy

Type of Program: Strategy for university and precollege education and outreach

Program Synopsis: To guide the development of university and precollege programs, the following matrix summarizing the desired background for graduates pursuing careers in Smart Lighting was developed with the assistance of all Center constituencies, with the largest impact coming from industry partners. This matrix, called the ***Illumineer Curriculum,*** is used to guide the development of all education and outreach activities for the Center.



To facilitate the delivery of the education and outreach programs while building the 21st Century Skillset in our graduates, we are also guided by our hierarchical student-to-student mentoring structure. All students, whether doing research in the lab or participating in a K-12 program, are mentored by and mentor other students. This adds to their educational experience and helps prepare them to be active ambassadors for Smart Lighting and STEM.

Contact person/website: Ken Connor (connor@rpi.edu) and Elizabeth Herkenham (herkee2@rpi.edu)

Dates of Operation/Timeframe: This program is continuous and ongoing.

Background: Smart Lighting, possibly even more so than the topics addressed at other ERCs, is very broadly multidisciplinary and involves background not generally found in any traditional STEM disciplines. Examples include lighting and other types of building design, human physiology and health, economics and business, etc. Our industry partners, especially, were finding that students graduating from excellent universities were not even conversant with the basics of lighting and those that knew

something about lighting design (e.g., from schools of architecture) knew nothing of the science and engineering of solid state lighting. To better understand what is needed we defined a new discipline we call *Illumineering*, to differentiate it from traditional Illumination Engineering. The matrix was also designed for the development of modules for education and outreach, but its usefulness is not tied to any particular delivery approach.

Methodology: We began the development of the *Illumineer Curriculum* by holding informal discussions with industry partners and then shared the ideas identified with all of our constituencies. The first versions of the curriculum matrix were produced collaboratively by the ERC Director Bob Karlicek and the Education Director, Ken Connor. Feedback on the matrix is obtained annually at our industry meeting, our faculty-staff-student planning retreat, etc., and continuously from everyone using it to guide the development of education and outreach content. One of the key steps in any of our programs is the identification of the aspects of the matrix included. Mentor training and mentoring activities are also formally included in all programs, with the present exception of those at the middle and elementary school levels. However, even the K-8 students are given information and tools they can share with their friends and family. They are not told explicitly of their mentoring opportunities but rather are empowered to show others what they have learned.

Impact/benefits: One of the most difficult tasks for those of us who are trying to develop new disciplines and industries is to help the people we work with understand what we are doing. The *Illumineer Curriculum* has been very helpful in telling our story. The student-to-student mentoring hierarchy helps our students understand how to be better engineer and scientist citizens in 21st Century society. In fact, it also helps them be better engineers and scientists.

Evaluation/Assessment: Each program has its specific assessment process utilizing surveys and general commentary from participants. We also utilize our student portfolios to track student development.

Sustainability: The methodology facilitated by the *Illumineer Curriculum* and our mentoring structure is not tied to any particular funding and thus will continue as long as it is useful.

Tip: Both of these ideas, the methodology behind the *Illumineer Curriculum* and the student mentoring hierarchy, must be used in every activity and must become part of the everyday vocabulary for everything in the Center. They cannot be seen as an add-on, but must be essential.

4.3.2 Research Experiences for Teachers (RET)

4.3.2.1 ***Center:*** Nanosystems Engineering Research Center (NERC) for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)
Lead Institution: North Carolina State University
Center Director: Dr. Veena Misra, Department of Electrical and Computer Engineering
***Name of Program*:** ASSIST Research Experience for Teachers (RET)

Type of Program: RET for middle and high school teachers [funded through ASSIST's core budget]

***Program Synopsis*:** The ASSIST RET program provides research experiences in systems engineering for middle and high school teachers. Participants partner with researchers to learn about all components of the Center, the mission of which is to develop nanodevices and sensors to create innovative battery-free, body-powered, and wearable health monitoring systems. To gain a systems perspective of engineering, teachers investigate all five thrusts that include: 1) energy harvesting and energy storage

devices, 2) low-power nanoelectronics, 3) wearable nanosensors, 4) integrated sensor design and prototyping, and 5) systems test beds. Investigations also include 3-D modeling and printing, benefits and limits of wearable sensors, thermal energy harvesting, and human factors related to medical devices. Finally, teachers create lessons for their students that integrate ASSIST research with cross-cutting concepts of size and scale, nanotechnology, and the Grand Challenges in Engineering.

Contact person/website: Dr. Gail Jones, Precollege Director, (mgjones3@ncsu.edu), http://assist.ncsu.edu/

Dates of Operation/Timeframe: Six-week program (summer and academic year experiences). We started this program for teachers in year 1 of our ERC. It is ongoing.

Background: The program was designed to meet the schools' goals of improving student achievement through investigations in nanotechnology, size and scale, as well as the Grand Challenges in Engineering.

Methodology: The program was designed by science educators and engineers in partnership with school administrators and ASSIST researchers. The instruction builds on educational research (determining program size and scale as well as nanotechnology education) and engineering research (energy harvesting and sensor design). The teachers' work enhances the Center's research goals.

Impact/benefits: The program provides experiences for teachers to learn about cutting-edge research in science and engineering, methods and tools of research, science/technology processes, engineering design, and education curriculum development. The program results in teachers who are more knowledgeable, more motivated, and enthusiastic about teaching relevant and engaging STEM topics, with an emphasis on engineering.

Evaluation/Assessment: Assessments of the impact of the first year's program included both research and evaluation. Through a partnership with another NSF project, Maximizing the Impact of STEM Outreach (MISO) [NSF award no. 1038154] we were able to assess how the project impacts teachers' and their students' attitudes toward STEM topics, confidence in doing engineering and science, interest in STEM careers, self-efficacy to learn STEM subjects, and motivation to continue to learn about engineering. Initial findings indicated that the teachers were highly satisfied with their RET experience; for example, a majority reported that it helped increase their confidence as teachers and increased their interest in teaching engineering and technology. In addition, we conducted educational research regarding teacher knowledge of size and scale concepts as well as systems approaches to learning science and engineering (results pending).

Sustainability: The RET program has created partnerships with the local schools and has brought in additional funds to support the teachers' participation.

Tip: The program's success has been enhanced by the involvement of research faculty who are gifted in their abilities to translate highly technical information into a form that is relevant and accessible to teachers. Such involvement by the ERC faculty should be a priority for ERC leadership.

4.3.2.2 ***Center:*** Biomimetic MicroElectronic Systems (BMES) ERC, a graduated ERC (2003–2013)
Lead Institution: University of Southern California
Center Director: Dr. Mark Humayun, Department of Ophthalmology and Biomedical Engineering
Name of Program: BMES ERC RET and other Teacher Professional Development Programs

Type of Program: RET for middle, high school, and community college science teachers (RET Site award direct to the ERC)

Program Synopsis: At the BMES ERC we conducted both a research experience for teachers (RET) program and a second teacher professional development program in middle schools across an entire district, using an associated grant from the California State Department of Education. The RET program was a 5-6 week summer program with teachers from middle and high schools and community colleges, while the second teacher professional development program (using Department of Education funding through the California Postsecondary Education Program, Improving Teacher Quality Program, or CPEC ITQ) was a middle school teacher and student program that included 53 teachers and 2,653 students. This second program included a 2-week summer program and monthly follow-up. Both programs had lesson study as a primary teacher professional development follow-up component and both programs targeted (a) teacher and student experimentation and inquiry via immersion in lab experiences, (b) science literacy for students, and (c) science motivation, interest, and engagement for students.

Contact person/website: Gigi Ragusa (ragusa@usc.edu) or Diana Sabogal (dsabogal@usc.edu)

Dates of Operation/Timeframe: We started this program suite for teachers in year 1 of our ERC. It is ongoing and fully developed.

Background: Comprehensive teacher professional development programs

Methodology: Partnership with Los Angeles Unified School District and other neighboring K-12 and community college districts.

Impact/benefits: The focus is on getting teachers better prepared to teach STEM content in courses and providing them with contemporary, cutting-edge STEM research experiences.

Evaluation/Assessment: Five assessment metrics were used to judge the success of the teacher and associated student intervention programs (RET and CPEC ITQ). These include a teacher instructional performance measure; a science teaching efficacy measure; a student science concept inventory; student science literacy measure; and a student science motivation, engagement, and interest measure.

Teacher Metrics:

- *Teacher Instructional Performance Metric:* A rubric scored observational assessment of science teacher instructional performance aligned to California's teacher performance assessment entitled Performance Assessment of California's Teachers (PACT).

- *Science Teaching Efficacy Beliefs Instrument Revised (STEBI-R):* This instrument is a teacher metric that assesses the teacher's efficacy in teaching science to middle school and high schoolers. It includes personal science teaching efficacy and science teaching outcome expectation, and is administered as a pre- and post-test to all teacher participants and compared to non-participant science teachers that match the participant teachers demographically (national averages).

Student Metrics:

- *Science Qualitative Reading Inventory:* This metric measure students' science literacy by grade level. It includes a measure of science vocabulary, reading comprehension, and science writing and is matched in terms of grade level science content and vocabulary.

- *Grade and Content Specific Concept Inventories:* These concept inventories measure grade-leveled concepts critical to scientific understanding.

- *Motivation for Science Questionnaire.* This questionnaire measures students' interest, motivation, and engagement in science.

Sustainability: This program has been institutionalized in LAUSD and is currently under revision for sustainability (pending funding).

Tip: Start designing programs in outreach early and work at sustainability early on (at least by year 3-4).

4.3.2.3 ***Center:*** Synthetic Biology Engineering Research Center (SynBERC)
Lead Institution: University of California at Berkeley
Center Director: Dr. Jay Keasling, Dept. of Chemical Engineering; Dept. of Bioengineering
Name of Program: Berkeley Engineering Research Experiences for Teachers (BERET)

Type of Program: RET Site award direct to the ERC

Program Synopsis: BERET focuses on the intersection between engineering, science, and mathematics through the interdisciplinary lens of synthetic biology. The program places *in-service and pre-service teacher teams* within faculty research laboratories and guides them to develop curricula based on their research that is relevant to the subjects that they teach in school and aligned with the educational standards for the subject addressed. BERET is jointly run by SynBERC and the Cal Teach science and mathematics teacher education program. The program has provided training for 52 teachers over a 3-year period. In-service teachers are middle and high school teachers who teach in diverse urban schools and have at least 3 years of teaching experience. Pre-service teachers are UC Berkeley undergraduates enrolled in Cal Teach, an undergraduate teacher development/training program. As follow-up to the summer, pre-service teachers teach their approximately 1-week curricular unit in the in-service teacher's classroom.

Contact person/website: Kate Spohr (kspohr@berkeley.edu), http://qb3.berkeley.edu/synberc/ret.html

Dates of Operation/Timeframe: The program was begun in 2012. It is an 8-week summer program that begins in mid-June and ends in mid-August.

Background: BERET was created to address a number of needs: 1) improve the quality of science instruction by providing teachers with authentic engineering research experiences that connect to K-12 science and mathematics teaching and curriculum development; 2) provide opportunities for veteran teachers to mentor teachers-in-training and provide teacher trainees with teaching opportunities; and 3) provide both in-service and pre-service teachers with new skills to help them apply the eight core scientific and engineering principles that are integrated into California's Next Generation Science standards.

Methodology: BERET takes advantage of CalTeach's expertise in teacher professional development and SynBERC's many years of experience in running an RET program that provides lab-based mentored research experiences to teachers. CalTeach and SynBERC piloted the program jointly in 2011 by placing two in-service/pre-service teacher pairs in a SynBERC Lab. The teachers worked together over the summer on a biofuels research project. The following fall, teams co-taught lessons in the in-service teacher's classroom. The success of the pilot inspired us to scale up the model by applying for an RET Site. During the past two years that BERET has been in existence, we have discovered that the benefits of mentoring within the teacher teams are a two-way street. Teachers adapt more quickly to the university environment when they are grouped with an undergraduate research partner. They benefit from the undergraduate's knowledge of current research practices and their familiarity and confidence with technology. The undergraduates, in turn, benefit from the teachers' perspective and their project management, communication, and people skills within the lab environment. They benefit in many ways from having the opportunity to work with exceptional and experienced teachers as role models. Further, they gain valuable curriculum development and teaching skills. Teams use their summer research

experience as the basis for developing new engineering lesson and curricular materials for classroom use. During and after the summer, teams will work together to develop a curriculum unit of several days to several weeks and then jointly teach it in the teacher's classroom during the academic year following the RET summer.

Impact/benefits: BERET is providing in-service and pre-service teacher teams with multidisciplinary engineering research experiences. In so doing, we are building a vibrant network of in-service teachers, pre-service teachers, and faculty, postdoctoral, and graduate student researchers that is resulting in long-term collaborative partnerships. Finally, our collaboration with CalTeach is enabling us to contribute to research in science education on how research experiences influence teachers and their teaching in secondary math and science classrooms.

Evaluation/Assessment: Evaluation is based on the following: 1) Pre-/post-participant evaluations measure participant understanding of the research process, understanding of engineering design principles, and how to incorporate these principles in K-12 science and math curricular design. 2) Lesson plans are analyzed using a rubric which measures how effectively lessons promote inquiry and an understanding of the research process, and integrate engineering with math and science content. 3) Classroom observation protocol is used to observe and analyze the implementation of lessons designed and taught by the pre-service teacher. 4) In-service teachers report on the success/challenges of implementing their lessons and on what their students learned based on student work from the lesson.

Sustainability: The program has become an integral part of the Cal Teach teacher training program. It is expected that the program's documented success will attract further funding from state, federal, and foundation sources interested in STEM teacher development.

Tip: The key to the successful pairing of an in-service with a pre-service teacher is to hire an in-service teacher who has a strong commitment/desire to mentor an undergraduate teacher trainee. Thus, in our BERET teacher job descriptions, we are now explicit about the mentoring requirement. When we interview in-service teachers for BERET we focus on their skills and success as mentors.

RET teachers work in the lab with faculty at an ERC

4.3.2.4 ***Center:*** Center for Sensorimotor Neural Engineering (CSNE)
Lead Institution: University of Washington
Center Director: Dr. Rajesh Rao, Department of Computer Science and Engineering
Name of Program: Research Experiences for Teachers (RET)

Type of Program: RET for high school teachers [funded through CNSE's core budget]

Program Synopsis: During the summer, the CSNE runs a 7-week Research Experience for Teachers program for two to six high school science teachers. During the program, the teachers participate in ongoing research in UW Center-affiliated research laboratories. Teachers are provided with a $7,000 stipend, each laboratory that hosts a teacher receives a $500 supply budget; and the primary CSNE mentors of the teachers are each given $500 to travel to a scientific conference of their choosing. In addition to being integrated into laboratory research, the teachers spend time every week translating their laboratory experiences into a standards-based curriculum which they will teach in their classrooms in the following school year. This curriculum is available through the website for other teachers to use. CSNE education staff follow up with the teachers during the school year, visits their classrooms when they teach the new curriculum, and provide constructive feedback.

Contact person/website: Lise Johnson (liseaj@uw.edu), http://csne-erc.org/education/research-experienceteachers

Dates of Operation/Timeframe: 2012–Present, summer only (7 weeks), 40 hours per week

Background: As required for all ERCs, the RET program was proposed as part of the original grant and was implemented the first year that the Center was funded.

Methodology: The RET program is, at this point, funded entirely by the CSNE core budget. The RET application is posted online in November and is due February 1st. All applications and application materials (essays, transcripts, and letters of reference) must be submitted through the CSNE website. The CSNE education staff reviews the applications and selects participants. Offers are made on March 1st and prospective participants are given one week to respond. Teachers are placed in labs in pairs; the hosting labs are carefully chosen by the CSNE education staff based on the type of projects and the mentoring available. The teachers are put in contact with their mentors before the start of the program so that they can arrange any necessary prerequisites (human or animal subjects training, building permissions, etc.) well in advance of their arrival. Participants are paid biweekly.

Impact/benefits: The RET program is designed to reach a large number of high school students by giving their teachers the tools they need to bring cutting-edge scientific research into the classroom. The RET program not only expands the participants' knowledge base; it also kindles their enthusiasm for neural engineering. This is passed on to their students who will be exposed to neural engineering concepts early in the process of forming their academic and career plans.

Evaluation/Assessment: The CSNE contracts with external education evaluators at the Washington state-based private Center for Research and Learning. These evaluators have designed a post-program survey which they administer to the teacher participants. The survey measures the program's impact on the CSNE target skill sets and attempts to capture the participant's perceived benefit and the impact of the program on future educational plans.

Sustainability: We are currently applying for an NSF Site grant for the RET program.

Tip: It is important to define the expectations for both the teachers and the mentors in advance of the program. Mentors must understand that hosting a high school teacher is not the same as hosting an

undergraduate student and that different levels and types of mentorship are required.

4.3.2.5 ***Center:*** CURENT (Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks)
Lead Institution: The University of Tennessee
Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science
Name of Program: Research Experience for Teachers (RET)

Type of Program: RET for middle and high school teachers [funded through CURENT's core budget]

Program Synopsis: CURENT's RET program operates during the academic year and summer term. The summer RET program recruits Knox County and surrounding counties' middle school and high school science and math teachers to learn about electricity and the power grid so that authentic applications can be incorporated into their classroom curriculum. The program typically selects approximately five teachers of varying background and experience who will work as a cohort within a single office area. By the end of the summer term, each teacher is expected to have developed curriculum that can be incorporated into their classroom based on the state level of science or math standards. In addition, they have to present their research at the STEM Symposium at the University of Tennessee, Knoxville (UTK). Examples of projects have included a variety of hands-on activities constructing circuits, demonstrations of historical static electricity experiments, development of conductivity labs, experimentation with power generation, and control with microprocessors.

Contact person/website: Chien-fei Chen (cchen26@utk.edu), http://curent.utk.edu/education/precollege/ret/

Dates of Operation/Timeframe: 6 week summer program (9-4pm) or once a week during academic semesters.

Background: The RET serves the needs of teachers in many ways depending on their teaching content, interests, and students' grade level. All teachers are guided by their state curriculum standards and all students are introduced to energy and electricity units in early middle school grades. Unfortunately, these concepts are barely covered in most schools due to a lack of testing requirements and lack of teacher confidence in understanding the material. Therefore, an effective RET program is necessary by incorporating engineering learning, hands-on project design, and curriculum development.

Methodology: During the academic year, CURENT develops relationships with teachers by visiting the local schools and holding after-school events. Through word-of-mouth, teachers working with CURENT promote our activities by sharing their experiences, which generates interest in our RET program. CURENT advertises to other local schools to expand our current network of teachers. Teachers are evaluated for admission into the program by reviewing essays that explain how they would like to incorporate electricity concepts or engineering concepts into their classroom. Each teacher receives a stipend or biweekly salary. The cohort takes the same seminars that develop their knowledge of general practices, current research, and computer tools used by engineers. The close interaction between the teachers allows transfer of engineering knowledge and group reflection about their teaching practices and their understanding of student behavior. On a weekly basis, faculty and graduate students present information about their research areas with materials that have been developed previously for outreach events. By the end of the term the teachers are expected to submit a presentation, poster, and curriculum guides and presented their research at the STEM REU Symposium. Through seminars, field trips, and discussions with CURENT, the middle school teachers generally develop a better

understanding of the concepts of electricity and developed activities related to renewable resources using principles of engineering design. For high school teachers, a lack of applications beyond simple book problems often exists and the students do not see the connection to their life. In response to this problem, high school RET participants develop curriculum for new courses, develop projects using advanced tools, or utilize real datasets that impact the decisions of people and businesses that relate to the study of electricity and renewable.

Impact/benefits: This program strengthens teachers' knowledge related to electricity and engineering. The program encourages the development of hands-on activities that will be highly receptive to students. By the end of the term, teachers will have gained a greater confidence in portraying engineering in an accurate and positive way. With the great uncertainty teachers have about engineering and its practices, the lessons that are created have a much better connection to real life.

Evaluation/Assessment: Biweekly interviews are performed with each teacher to monitor their progress and interest in the program. Three surveys including pre-measure, post-measure, and follow-up are used to determine the teachers' overall perspective about teaching engineering. Lastly, program evaluations are used to evaluate the program structure and determine areas for improvement.

Sustainability: Three possible ways to sustain this program include: 1) leveraging with university organizations and local school system who have funding; 2) seeking grant opportunities from NSF (e.g., RET Site proposal) or other agencies; and 3) seeking financial support from faculty who have other NSF grants.

Tips:

- To facilitate interactions between participants including knowledge sharing and reflection, have the teachers work on their individual projects within a common office.
- Participants need an initial meeting prior to starting the program to collect their ideas so that specific ideas can be targeted.
- More structured training courses to introduce basic engineering concepts would enhance teachers' ability to concentrate on specific topics more quickly for their curriculum.
- A weekly meeting is very important to understand teachers' need and frustration. RET participants should have the flexibility to modify what they want to accomplish during the 6 weeks.
- A follow-up survey and communication is important to document the longer effect of this program.

4.3.3 RET with Multicultural Component

4.3.3.1 ***Center:*** Engineering Research Center for Integrated Access Networks (CIAN-ERC)
Lead Institution: University of Arizona
Center Director: Dr. Nasser Peyghambarian, Department of Materials Science and Engineering
Name of Program: Research in Optics for K-14 Educators and Teachers (ROKET)

Type of Program: An RET Site award director to the ERC

Program Synopsis: The target audience is teachers who teach to predominantly Native American K-14 students. Teachers spend 6 weeks at the University of Arizona performing research in optics and chemistry research labs. Each participant engages in a distinct "miniproject" which is carried out in their assigned lab with the help of a graduate student mentor and faculty mentor. In addition to the research experience, ROKET teachers complete (and receive 3 units of continuing education for) a 4-week course with the American Indian Language Development institute (AILDI). The course focuses on methods for integrating traditional ecological knowledge with modern science curriculum. These two dimensions (research lab and AILDI course) work together to excite teachers about STEM research as well as provide the instructional tools needed to impart this excitement to their students in the context of Native American culture, thus bringing more Native American students to college in pursuit of STEM degrees. In 2013, the Optics Research Workshop (ORW), a new component of the ROKET program, was implemented in an effort to bridge the gap between the K-14 classroom and University of Arizona research labs in a culturally competent way. In the ORW, training with pertinent research equipment occurs, as well as lessons and hands-on projects that assist teachers in understanding symbiotic relationships that exist between optics/STEM and Native American cultures and communities. This is an integral component that provides teachers of Native American youth an understanding and tools to help their students make similar connections.

Contact person/website: Dr. Allison Huff MacPherson (allison@optics.arizona.edu)

Dates of Operation/Timeframe: This six-week program runs from June to mid-July. The first ROKET program was implemented in the summer of 2009.

Background: Native Americans lag behind other underrepresented minorities in STEM higher education majors and STEM careers. This program endeavors to pique the interest of young students toward STEM through their schoolteachers, and ultimately encourage them to matriculate in a college or university majoring in a STEM discipline. The ROKET program is a critical component in the STEM pipeline for Native Americans.

Methodology: Nationwide recruiting for the ROKET program begins in October by populating the website (http://www.cian-erc.org/teachers.cfm) with applications, profiles of alumni, research project descriptions, program dates, and mentor bios. The ROKET program website is also registered with the NSF-sponsored database of RET programs nationwide, http://retnetwork.org/. Science educators are also recruited through existing local contacts such as AILDI and Native American-serving community colleges such as Tohono O'odham Community College and Dine College. Other nearby sources for recruitment include Arizona Indian tribes and reservations such as the Pascua-Yaqui, White Mountain, Apache, Navajo, and Hopi, to name a few. Participants are then selected from the applicant pool to create a diverse representation of tribes and regions of the United States. An offer email is sent to each selected participant asking for their confirmation and commitment; once a confirmation response is received, initial instructions and paperwork are sent out. This paperwork includes a Participant Contract, Travel and Housing Arrangements, Risk Release forms, instructions to apply to the university's graduate college, and a request for items such as copies of IDs and social security cards (for university registration).

Meanwhile, during the applicant selection/acceptance process, faculty and graduate student mentors are selected and confirmed. Also, contact is established with the on-campus housing coordinator to initiate housing reservations for the participants. Another important step is to notify the Graduate College admissions office of the names of the RET participants so they can be sure to admit them and subsequently notify the RET program coordinator of their admission.

Other important items that are completed in advance are room reservations for program activities,

establishing an exact schedule of lab time, the delivery of a grad student mentor training, and airline reservations for those who opt to fly rather than drive.

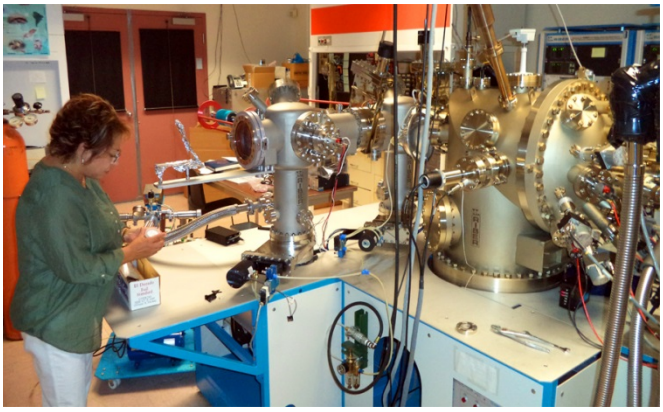
Throughout the course of the program, RET participants are interviewed on a bi-weekly basis to collect continuous feedback, and pre- and post-program surveys are given to measure changes in confidence and knowledge concerning science and research processes. At the end of the six-week program, oral presentations are given by each RET about their individual research projects, and a poster session is also held to display their work.

Impact/benefits: Outcomes reported by teachers include an improved understanding of available career and education opportunities for their students in science and engineering fields. Each teacher develops an original lesson plan that introduces modern optical technology to their students, while simultaneously referencing the history of scientific thought and discovery among their Native American ancestors. Teachers have also reported an improved perspective on the skills needed by their students to achieve success in these areas. Presentations at national conferences are also common among ROKET participants.

Evaluation/Assessment: Evaluation tools include pre and post-program surveys (administered via surveymonkey.com) to measure changes in knowledge, skills, and attitudes, as well as biweekly interviews throughout the program and a focus group at the conclusion of the six weeks. The focus group and interviews provide a more intimate view of each individual's experience with the RET program, allowing the program coordinator and Education Director to take all ideas into account when modifying the program the following year.

Sustainability: Seeking other sources of funding to continue implementing the ROKET RET program is essential to the program's sustainability.

Tips: It is recommended that faculty mentors be urged to decide on a project with their RET a month in advance so they can order lab supplies and have them ready when the teachers arrive. Also, assure that graduate student mentors are clear on their responsibilities and expectations; that way they can confidently lead their mentee through the research process.



An RET teacher in the lab at CIAN

4.3.4 High School Programs

4.3.4.1 ***Center:*** Biomimetic MicroElectronic Systems (BMES) ERC, a graduated ERC (2003–2013)
Lead Institution: University of Southern California

Center Director: Dr. Mark Humayun, Department of Ophthalmology and Biomedical Engineering

Name of Program: BMES ERC Engineering for Health Academy

Type of Program: Precollege grades 10-12

Program Synopsis: In an effort to increase awareness and support of science and engineering among precollege students, BMES ERC established the Engineering for Health Academy (EHA). This program is designed as a small learning community within the context of the larger comprehensive high school. The major goals of this program are to introduce high school students, including English language learners and underrepresented minorities (Table 2) to the broad spectrum of biomedical engineering (BME) career opportunities. EHA students make a three-year commitment to the program beginning in the 10th grade and transition through a series of 4 integrated core courses (chemistry, physiology, computer sciences, and physics) in grades 10 through 12. Each EHA course is standards-aligned, rich in relevant hands-on activities, project-oriented and meets high school graduation requirements. Curricular development is driven by current/ future anticipated needs of the BME field so that graduating EHA students will have advanced preparation for the demands of a rigorous post-secondary college program and/or careers in biomedical engineering.

Students in 12th grade are matched with ERC labs in BMES and spend a minimum of two hours every school day working as part of a research team on an engineering project. Mentoring is a critical component in this capstone class. USC postdocs and graduate and undergraduate students help the EHA seniors navigate the challenging transition from a structured high school classroom into a university research environment. In partnership with their mentors the EHA students develop and execute an appropriate yearlong research project. They guide the EHA students in the formulation of scientific hypotheses and experimental designs to test those hypotheses. They train the students in scientific protocols and methodologies, help them collect and analyze data, and draw defensible conclusions.

EHA students enrolled in the Research Experience class receive 10 course unit credits that count toward their UC/CSU A-G high school graduation requirements. This capstone class enables students to utilize the factual information and technical skills they acquired in the EHA core classes and put them into practice in a research environment. It also increases the students' self-efficacy and prepares them for the rigors of a college science and engineering course of study.

EHA students are required to present their research findings at a seminar series scheduled each spring semester as part of their Research Experience class. Laboratory principle investigators, USC mentors, and fellow EHA students from all three grade levels attend these seminars and learn about the broad spectrum of EHA-associated research topics. The feedback students receive during the seminars helps them in the preparation of posters they present at the annual USC/Bravo Science and Engineering Fair in March. Professionals from USC and other institutes of higher education serve as judges at the fair. Depending on the quality of their work, select students are eligible to participate at the Los Angeles County and California State Science and Engineering fairs. USC mentors are an important and key resource to the EHA seniors as they prepare their seminar presentations and science fair posters. All EHA students are required to work on a research project every year they are in the program, not just as part of the Research Experience capstone class. Students may work individually or as a team. As expected, the projects typically become successively more complicated and detailed as the students progress though the EHA program, culminating in highly sophisticated projects that reflect the work completed as part of the capstone class. Working with EHA teachers and USC mentors, students decide upon projects that are of interest to them and feasible to undertake.

Contact person/website: Joe Cocozza (cocozza@med.usc.edu) or Diana Sabogal (dsabogal@usc.edu)

Dates of Operation/Timeframe: We started this program in year 6 of our ERC. It is ongoing and fully developed.

Background: Comprehensive cohort Young Scholars type program, grades 10-12

Methodology: Partnership with Los Angeles Unified School District (LAUSD)

Impact/benefits: The focus is on getting students in grades 10-12 exposed to and interested in BMES focused science and engineering. Students are well prepared for college STEM majors resulting from this cohort-based, small learning community type program.

Evaluation/Assessment: Program assessment is a key component of the Engineering for Health Academy. A variety of measurements and assessment instruments are employed, including: an interest and motivation in science survey; results on the California Standardized Tests (CST) in chemistry, physics and mathematics; the number of students applying to 4-year institutes of higher education; the choice of college major; and the quality of projects entered into the Science and Engineering Fair. The CSTs are designed by California educators and test developers specifically for California. They measure students' progress toward achieving California's state-adopted academic content standards, which describe what students should know and be able to do in each grade and subject tested. The NCLB objective is to have all students proficient in each area tested.

Sustainability: This program has been institutionalized in LAUSD and is currently under revision for sustainability (pending funding).

Tip: Start designing programs in outreach early and work at sustainability early on (at least by year 3-4).

4.3.4.2 ***Center:*** Center for Subsurface Sensing and Imaging Systems (CenSSIS), a graduated ERC (2000–2010)
Lead Institution: Northeastern University
Center Director: Prof. Michael B. Silevitch, Dept. of Electrical and Computer Engineering and Dept. of Civil and Environmental Engineering
Name of Program: High-Tech Tools and Toys Laboratory

Type of Program: Innovative educational facilities for engineering freshmen and high school students

Program Synopsis: CenSSIS created a novel approach to learning at its High-Tech Tools and Toys Laboratory (HTT&TL) facilities for engineering freshmen and high-school students. The intent was to engage student learning through the use of computers to control high-tech imaging systems.

Contact person/website: Dr. Claire Duggan (c.duggan@neu.edu)

Dates of Operation/Timeframe: Not available

Background: This approach is not only more relevant to engineering practice than traditional “chalk and talk” classes, but is also more accessible to women, minorities, and other student populations that are not proportionally attracted into science and engineering careers.

Methodology: The program was piloted at Northeastern University (NU) by funding a relatively modest upgrade for an existing instrumentation/computer laboratory to add computer-controlled x-y positioners and ultrasound pulse-echo transducers. In a program modeled on modern medical imaging

technology, engineering freshmen learn to program the computer to raster-scan the transducers and analyze the ultrasound signal channel to image an object concealed under opaque gelatin.

Impact/benefits: HTT&TL facilities with ultrasound, optical imaging, and robotics instrumentation were established at the other three CenSSIS universities--Boston University, Rensselaer Polytechnic Institute, and the University of Puerto Rico at Mayaguez--and were used to enhance freshmen learning and engagement in engineering. In addition, a CenSSIS faculty member at NU collaborated with a Boston Public School teacher and summer Research Experience for Teachers (RET) participant to offer the HTT&TL experience to 19 primarily minority, non-traditional students who were returning to school to earn their High School diplomas from the Boston Adult Technical Academy. The success of this program served as a model for extending the HTT&TL approach into K-12 education.

The CenSSIS High Tech Tools and Toys Lab excites at-risk students about entering careers in science and engineering.

Evaluation/Assessment: Student enthusiasm for the experience is reflected in end-of-class surveys that showed that 100% of students would recommend the course to their friends. Follow-up surveys in a subsequent programming class indicated that students rated their learning of computation and engineering in the HTT&TL environment much higher than students from traditional classroom sections.

Sustainability: Not available

Tips: Not available

4.3.4.3 ***Center:*** Center for Compact and Efficient Fluid Power (CCEFP)
Lead Institution: University of Minnesota
Center Director: Dr. Kim Stelson, Department of Mechanical Engineering
Name of Program: Cooperation with Industry and Project Lead The Way

Type of Program: Precollege curriculum development

Program Synopsis: Fluid power is included in a number of courses taught through a nationwide program for middle and high school students because of a successful partnership between the National Fluid Power Association (NFPA) and educators affiliated with the CCEFP. What started as cooperation in reviewing class curricula has grown into volunteers now also teaming with writers from Project Lead The Way (PLTW) to develop altogether new course material as part of PLTW's nationwide effort to promote teaching in Science, Technology, Engineering, and Mathematics.

Contact person/website: Alyssa Burger, aburger@umn.edu

Dates of Operation/Timeframe: 2008-2010

Background: The effort is just part of the CCEFP's effort to find partnerships with highly regarded and broadly distributed education and outreach networks in order to maximize the impact of Center programs.

Methodology: Following a successful pilot at one university in 2008, the Center and the NFPA worked to involve teachers associated with Project Lead the Way in the CCEFP's 2009 Research Experience for Teachers program at five partner universities. The teachers developed course materials based on their experiences in Center labs, sharing them with their students and with colleagues through the Center and PLTW networks.

Impact/benefits: The Center and NFPA are now cooperating in other projects of the PLTW, which is teaching courses to more than a quarter million students in more than 3,000 middle and high schools in all 50 states. Members of the CCEFP's Student Leadership Council, for example, have videotaped themselves as they talk about their paths to engineering and their roles in Center research. The clips are used by PLTW to inspire precollege students as they make career choices.

Evaluation/Assessment: Not available (contact Ms. Burger)

Sustainability: Not available (contact Ms. Burger)

Tips: Not available (contact Ms. Burger)

Fluid power engineering is being introduced to middle and high school students nationwide through Project Lead The Way, due to collaboration between the CCEFP and its industry partners on innovate course materials.

4.3.4.4 ***Center:*** Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)
Lead Institution: Stanford University
Center Director: Dr. Richard Luthy, Department of Civil and Environmental Engineering
Name of Program: Eastside Prep Water Science and Engineering class

Type of Program: Partner high school class

Program Synopsis: The 2013 Eastside Prep Water Science and Engineering was a summer class for 19 rising sophomores, taught by ReNUWIt's Dr. Pam McLeod. Class activities included labs, field trips (e.g., Stanford University, a local creek, a wastewater treatment plant), model building, design challenges, and

inquiry-based learning techniques. At the end of the class, students created short, 3-5 minute films for a class film festival. Dr. McLeod developed the course materials with assistance from 2012 and 2013 ReNUWIt RET Mrs. Ann Akey. Several ReNUWIt post-docs and graduate students also helped teach selected modules.

Contact person/website: Dr. Pam McLeod, Education and Outreach Manager (pamelamc@stanford.edu), www.renuwit.org

Dates of Operation/Timeframe: The class ran for 6 weeks, June 17–July 26, 2013. It met for three hours per day, Monday through Friday. Additionally, a significant amount of prep work was required to plan the overall syllabus and daily activities.

Background: Eastside College Preparatory School is Stanford University's K-12 partner institution. Eastside serves 100% underrepresented minorities, with over 97% first-generation college attendees; their college acceptance rate is 100% but very few declare majors in the STEM fields. Initial discussions with Eastside's principal led to the idea of a ReNUWIt-led summer class, since all of Eastside's students are required to take summer electives. Earlier in 2013, Eastside indicated that a 6-week class would best meet their students' needs. The school felt comfortable with ReNUWIt offering the class with one consistent teacher throughout (Dr. McLeod had experience teaching high school biology).

Methodology: Initial meetings and follow-up discussions between Dr. McLeod and Eastside administrators established Eastside's needs and a general framework for summer class logistics. Dr. McLeod drafted a course introduction, course outline, and general syllabus with assistance from Woodside High School teacher (and RET) Ann Akey. Dr. McLeod served as the main instructor for the class, which met 9am–noon every weekday for six weeks. Eastside advertised the class to its students using the provided course introduction and pictures, and was responsible for student enrollment and classroom/scheduling logistics. The main goal of the class was to interest students in water science and engineering, achieved through a mix of hands-on activities/labs, design challenges, and interactive discussions. Skills including Excel spreadsheets, public speaking, math, and writing were emphasized. Materials used in class were (1) purchased by ReNUWIt, (2) borrowed from Mrs. Akey, and/or (3) borrowed from Eastside Prep. The class used Schoology for assignments and sharing documents. ReNUWIt post-docs and graduate students were also involved in some of the class periods, teaching selected modules.

Impact/benefits: The summer program strengthened the relationship between ReNUWIt and Eastside Prep, exposed students to water science and engineering, and gave ReNUWIt post-docs and graduate students an opportunity to interact with high school students in a meaningful way. Much of the class content was directly applicable to students' lives, and they shared what they learned with peers and family members. It is hoped that this class will help increase general water science awareness, and inspire more young people to pursue majors and careers in STEM disciplines.

Evaluation/Assessment: In the first year of the class, students were given post-class self-report surveys to assess their attitudes toward STEM and water science/engineering, gauge their familiarity and comfort level with certain skills, and solicit feedback for class improvements. Dr. McLeod will also meet with Eastside administrators to discuss their reaction to the class and begin discussing plans for summer 2014. In subsequent years, pre- and post-program assessments will be administered.

Sustainability: Whenever possible, materials used in class were purchased or obtained from everyday sources, and selected to be inexpensive, reusable, and durable. The syllabus and lesson plans were documented. In the future, a non-ReNUWIt teacher could teach the class based on these materials.

Tip: Developing and teaching a 6-week, 3-hour/day class for 19 rising sophomores represents a

significant time commitment for an ERC staff member. It is imperative to discuss expectations, school culture, available resources, and needs/wants ahead of time with school administrators.

4.3.4.5 ***Center:*** ERC for Biomimetic MicroElectronic Systems (BMES), a graduated ERC (2003–2013)
Lead Institution: University of Southern California
Center Director: Dr. Mark Humayun, Department of Ophthalmology and Biomedical Engineering
Name of Program: High School Student Mentoring

Type of Program: High School Student Research

Program Synopsis: A high school student was first mentored by a BMES faculty member, then accepted as a member of his lab's research team, where she conducted cutting-edge research on optics and optical systems design. She was and still is the only high school student ever to become a full member of the lab.

Contact person/website: Mark Humayun (humayun@usc.edu)

Dates of Operation/Timeframe: 2003–2008

Background: Most precollege programs offered by universities aim to give young students a glimpse into the fascinating world of science and engineering, in order to spark their interest in these subjects for further study. The BMES ERC, at the University of Southern California (USC), found one precocious student in whom that spark became a flame. Noelle Stiles, then an 11th-grader at Villa Park High School, began working with BMES Prof. Armand R. Tanguay, Jr., in Fall 2003 after she was introduced to him at a science fair. Initially, Tanguay mentored her science fair project, and then accepted her as a full member of his Optical Materials and Devices Laboratory at USC when it became apparent that she was deeply committed to her research.

Methodology: At the outset, all of Noelle's research work was on a volunteer basis, under the auspices of various science fairs. When she became a member of Tanguay's research group, she also became affiliated with the BMES ERC and began participating in weekly meetings of the Retinal Prosthesis Research Group at the USC Keck School of Medicine. She attended an FDA surgical trial of a retinal prosthetic microelectrode array (implanted by BMES Director Dr. Mark Humayun), and participated intensively in the successful surgical implantation of the first intraocular camera in a dog's eye in July 2004.

High school student Noelle Stiles, in the lab at the BMES ERC, displays the first-generation intraocular camera.

In the 2004 Orange County Science & Engineering Fair, Noelle's project, "Intraocular Camera for Retinal Prostheses: Restoring Vision to the Blind," took the Grand Sweepstakes Award, Senior Division (9-12) (the top prize of the entire Fair); First Place, Physiology, Senior Division (9-12); and First Place, Center for Inquiry West (an organization founded by Carl Sagan and Murray Gell Mann), for the best project demonstrating critical thinking. That same year Noelle was named a semifinalist in the Siemens Westinghouse Competition in Math, Science, and Technology at the national level. As such, she was recognized as one of an elite 300 math, science, and engineering students in the entire country.

Entering USC as an undergraduate, Noelle continued her research within Dr. Tanguay's research group and the BMES ERC on the visual psychophysics and optical systems design criteria applicable to both intraocular and extraocular camera designs for retinal prosthetic devices. Less than three years after discovering her passion for biomedical research as a high school junior, this remarkable young student was routinely presenting her research at professional conferences, where she was accepted as a peer. ***Impact/benefits:*** At present, Noelle is a doctoral student in the computation and neural systems (CNS) program at Caltech. Her graduate research focuses on the design and evaluation of sensory substitution devices for rehabilitation of the blind—a direct progression from her science fair project a decade ago that was inspired by her early association with the BMES ERC.

Evaluation/Assessment: Not available

Sustainability: Not available

Tips: Not available

4.3.5 Middle School Programs

4.3.5.1 ***Center:*** CURENT (Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks)
Lead Institution: The University of Tennessee
Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science
Name of Program: MITES (Middle School Introduction to Engineering Systems)

Type of Program: Precollege, summer weeklong program, a collaboration between the Office of Diversity at the University of Tennessee and CURENT

Program Synopsis: The MITES program is a group of thirty-two 7th and 8th grade students from across the state of Tennessee who are interested in science and mathematics. Half of the participants are from underrepresented population groups. The purpose of MITES is to help middle school students develop a better understanding of engineering, math, and the design process. The unique feature of the program is that all students live in a campus residence hall with undergraduate supervisors and the students' daily schedule mimics the activities of a typical college student. During their class periods, students attend 4 classes each day. The program incorporates hands-on activities related to mathematics, engineering competitions, engineering career awareness, and a tour of the American Museum for Science and Energy as part of their experience. CURENT hosts the engineering design and learning sections, including basic concepts of electrical engineering and renewable energy. Students designed a hands-on microgrid project based upon their earlier class experiences. This project includes the design of an open-close circuit, a motor, a solar car, a solar house and wind turbines.

Contact person/website: Chien-fei Chen, Education and Diversity Co-director (cchen26@utk.edu)

Dates of Operation/Timeframe: 5-day summer residential program. Note: In 2012, two programs were offered and in 2013, one program was offered.

Background: MITES has been reaching out to middle school students since 1997 and has been tracking their interest in science and mathematics as they progress through high school. MITES has been shown to increase the interest of students in studying engineering. Many of the counselors, who are undergraduates in engineering, are former participants of the program.

Methodology: There are several different sections and activity periods throughout the day. CURENT prepared activities that introduced a brief engineering topic and then explored the concepts by watching demonstrations or by building certain types of models relating to the concepts. Concepts such as static electricity, circuits, solar energy, wind energy, and power generation were explored during the program. The students also constructed out of cardboard boxes a model house that had a solar-powered doorbell, a wind turbine-powered yard light, a solar car, and a generator-powered door light, used to build a microgrid. At the end of the fourth day, the students presented what they learned and their final projects.

Impact/benefits: This program exposes students to engineers and the type of work that engineers typically do. Not only do the students gain a better understanding of the science behind electricity, the students also have opportunities to construct models and use the engineering design process. The low-

risk atmosphere of the camp allows students to explore their ideas without worrying about grades. The students' outlook on engineering is positively impacted.

Evaluation/Assessment: Pre and post surveys were used to determine learning, interest, future intention, and attitudes toward engineering. Selective interviews were also conducted.

Sustainability: Leveraging with university organizations or industry partners is a way to sustain. The program utilizes reusable materials that are typically inexpensive. MITES typically has funding from companies.

Tips:

- Due to the large quantity of materials and the rapid pace of the summer camp, large amounts of materials need to be ordered weeks in advance and organized into lesson-based kits. The best materials could be the recycled and cheap ones.
- All materials need to be accessible and prepared in quick handouts to keep the students in constant action. Alternative tasks should also be developed for students that are not interested in the main activity.
- Multiple methods of constructing models/activities need to be developed so that a range of challenges and scaffolds can be provided.
- Lessons should be flexible enough that critical portions can be easily covered in the given time, but can also be expanded with additional mini-lessons that can be used for groups that are fast at finishing tasks. The mini-lessons do not need to be completed if it is time to move to the next activity.
- All activities should be made so that the next activity can be started as soon as an earlier activity ends. There should be no downtime.
- Incorporate activities that can be used at any time to refocus students.
- Try to find helpers that are used to working with the campers' age range. Those helpers will be more in-tune with how to change activities based on the students' behaviors.
- Behavioral expectation needs to be explained in the beginning of the program. Instructors need to create a good classroom learning environment and know how to interact with middle school students.

4.3.5.2 ***Center*****:** Smart Lighting ERC
Lead Institution: Rensselaer Polytechnic Institute
Center Director: Prof. Robert F. Karlicek, Jr., Dept. of Electrical, Computer & Systems Engineering
Name of Program: RPI Engineering Ambassadors Program

Type of Program: Precollege program

Program Synopsis: The Rensselaer Engineering Ambassadors program was developed to support the overall mission of precollege education outreach for the School of Engineering including the Smart Lighting ERC. It has two key goals: 1) to help Rensselaer undergraduate students develop excellent

communication skills by giving them the training and opportunity to teach engineering technology to a younger audience of middle and high school students and 2) to inspire K-12 students to pursue academic degrees and careers in Engineering by showing them that engineers solve critical problems that impact the quality of life, health, and safety of society. The program is supported through corporate fund, faculty broader impact efforts, ERC precollege funding, institute undergraduate research program match funding (URP), and private grant funding.

Program contacts: Elizabeth Herkenham, Director, K-13 Education Outreach, SoE Rensselaer Polytechnic Institute (herkee2@rpi.edu), http://eng.rpi.edu/ea)

Facebook: RPI Engineering Ambassadors

YouTube: RPIEngAmbassadors

Note: For details on this program, see example 4.4.11.1 in the appendix to sec. 4.4, Undergraduate Education

Background: The RPI Engineering Ambassadors (EA) Program began in January 2011 with the support of a corporate sponsor, United Technology Corporation. The Rensselaer program was modeled after the Penn State Engineering Ambassadors program developed in 2010 that included extensive communication training, Assertion–Evidence presentation style and creative hands-on activities. The Rensselaer program has grown from 4 students in Spring of 2011 to approximately 30 undergraduates students today (Fall 2013).

Methodology: Undergraduates are selected through a competitive recruitment process that looks for students with strong academic standing and a passion for education outreach.

The RPI Engineering Ambassador network connects with local urban, rural, and suburban school districts to schedule school-wide visits. Typically 4–5 EA teams representing different engineering topics travel to 12–14 regional school districts each academic year.

During each visit, an individual EA team would present within a school district's classroom schedule potentially 4 times, exposing over 80 precollege students to engineering. Four to five EA teams would result in 320–400 students exposed per school visit. This infrastructure of a well-prepared EA army of undergraduates travelling to regional school districts can conservatively expose 3800 precollege students to the "Better World Engineering."

Impact/ Benefits: The RPI Engineering Ambassadors program has been an effective tool for spreading the message of the NAE Report, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. The program has also improved the technical communication skills, confidence, and creativity of presentations of the undergraduates involved. It is a win–win outcome for both the young audience and undergraduate presenters.

Evaluation / Assessment: The Smart Lighting ERC External Evaluator, Evaluation Consortium has studied the program's effects on the EAs over the last two years. Through the support of the Smart Lighting ERC, Rensselaer performed an informal review of the effectiveness of the presentations during the inaugural year 2011–2012. Over 1,500 middle and high school students were surveyed with a pre-and post-EA school visit program evaluation that focused on their attitudes towards engineering. In summary:

- 60% agreed the presentation helped them to better understand engineering
- 49% agreed that their interest in engineering had increased as a result of the presentation
- 58% agreed that their knowledge of engineering had increased as a result of the presentation.

These preliminary results suggest that the Engineering Ambassadors program is effective and beneficial; however, further studies need to be conducted in order to substantiate the results.

Sustainability: Rensselaer has successfully integrated the program within our research landscape; therefore, the program has also been a useful method for faculty and/or research centers to share the importance and benefits of specifics of cutting-edge research or the overarching purpose of a research effort.

Tip: Program improvements could be made in future years by working with K-12 educators to align relevant EA modules to the learning standards requirements within specific subject areas.

4.3.6 Elementary School Programs

4.3.6.1 ***Name of Center:*** Biomimetic MicroElectronic Systems ERC (BMES ERC), a graduated ERC (2003–2013)
Lead Institution: University of Southern California
Center Director: Dr. Mark Humayun, Department of Ophthalmology and Biomedical Engineering
Name of Program: BMES Science for Life Program

Type of Program: Precollege grades 3-5

Program Synopsis: Over the past 10 years of the BMES ERC, we developed and implemented our Science for Life Program. The Science for Life (SFL) outreach program is a collaborative science education initiative between the BMES ERC and Murchison Elementary School (MES). MES is a Title 1 school with a Hispanic student population of ninety-seven percent. In the 2010-2011 academic year, BMES ERC faculty members and USC students joined Bravo Medical Magnet High School students and 11 Murchison Street Elementary School teachers in serving as in-class mentors for 3 science and engineering modules delivered to all 247 of MES' 3rd, 4th, and 5th graders. This effort represented 369 contact hours between mentors and students, bringing the excitement of discovery to an inner city elementary school.

Contact person/website: Joe Cocozza (cocozza@med.usc.edu) or Diana Sabogal (dsabogal@usc.edu)

Dates of Operation/Timeframe: We started this program in year 2-3 of our ERC. It is ongoing and fully developed.

Background: Modular program in grades 3-5.

Methodology: Partnership with Los Angeles Unified School District (LAUSD).

Impact/benefits: The focus is on getting students in grades 3- 5 exposed to and interested in BMES-focused engineering and science. Over 300 students have benefited from this program.

Evaluation/Assessment: We conducted a science and engineering interest survey for students to measure changes in students' interest in science and engineering across the three grade levels. We also track students' California Standards Test (CST) achievement test results across their years in school to monitor changes for those participating in the Science for Life program.

Sustainability: This program has been institutionalized in LAUSD and is currently under revision for sustainability (pending sustainability funding).

Tip: Start designing programs in outreach early and work at sustainability early on (at least by year 3).

4.3.6.2 ***Center:*** NSF ERC for Re-Inventing America's Urban Water Infrastructure (ReNUWIt)
Lead Institution: Stanford University
Center Director: Dr. Richard Luthy, Department of Civil and Environmental Engineering
Name of Program: K–8 Educational Excellence Initiative

Type of Program: Outreach

Program Synopsis: This program is modeled after the NSF Graduate STEM Fellows in K-12 Education (GK-12) program. Teachers who are drawn from local school districts and who provide instruction in mathematics and science in grades kindergarten through eighth grade complete a two-week summer workshop on earth, energy, and environment. Several of the sessions of this workshop focus on the work of ReNUWIt researchers. Participating teachers, in collaboration with our graduate students, convert these lesson plans into classroom modules. Graduate students provide support throughout the academic year in the implementation of the modules in the classroom.

Contact person/website: Barbara M. Moskal, Colorado School of Mines (bmoskal@mines.edu)

Dates of Operation/Timeframe: Two weeks in the summer, full academic year.

Background: This program provides elementary school teachers with the knowledge they need to inspire young students in science, mathematics, and engineering.

Methodology:

- Recruitment of schools and teachers occurs throughout the spring semester.
- Principals and teachers agree to program participation by May and in writing.
- Recruitment and development of lesson plans occurs throughout the spring semester by Colorado School of Mines faculty.
- Graduate students are recruited to the program through direct mailings and faculty recommendations. Offers are made in spring and contracts signed by May.
- Lesson development occurs throughout May and June.
- A two week workshop occurs in July, and follow-up classroom visits continue throughout academic year.

Impacts/benefits: This program is important because it fills a gap in teachers' understanding of mathematics and science. This has a secondary impact on students' mathematical and scientific learning, as well as their interests in the field.

Evaluation/Assessment: We use focus groups with both fellows and teachers, as well as questionnaires at various times throughout the program. We also administer a pre- and post-assessment to participating teachers and an "attitudes toward science and mathematics" instrument to students. Treatment and control groups are available for the student population.

Sustainability: This program has been structured such that any funded research program can participate by providing instruction at the summer workshop. The participating faculty can also contribute supplies or the efforts of a graduate student.

4.3.7 Partnerships with School Districts

4.3.7.1 ***Center:*** Quantum Energy and Sustainable Solar Technologies (QESST)
Lead Institution: Arizona State University
Center Director: Dr. Christiana Honsberg, Department of Electrical Engineering
Name of Program: Liberty Elementary School Partnership (Buckeye, Arizona)

Type of Program: K-12 Meaningful Partnership

Program Synopsis: QESST has developed a multi-year partnership with the Liberty Elementary School District. The purpose of this partnership is to help build the pipeline for future solar photovoltaics (PV) engineers. To do this, QESST seeks to motivate and engage students in engineering activities designed for students in the K-8 classroom.

Contact person/website: Jenefer Husman, Education Director (jenefer.husman@asu.edu), Christi Mendoza, Precollege Education and Outreach Coordinator (christine.mendoza@asu.edu)

Dates of Operation/Timeframe: This program is a multi-year partnership that began in the spring of 2012. The program takes place during the semester during classroom science instruction time (approximately 60 minutes) every school day for about five weeks. Additional program activities are held for select events in the evenings. Professional development events are also held on select days determined by the district.

Background: Although the bulk of the technical training required to become a thought leader in PV engineering occurs at the university level, to invigorate PV research and manufacturing in the US, students need to enter college with strong science and engineering knowledge and skills as well as an interest in engineering in general and solar energy specifically. The QESST team is well aware of the new changes to National science and engineering standards as part of the adoption of the Next Generation Science Standards (NGSS). The QESST educational team is working to support schools as they move to adopt NGSS by creating active learning units, engineering design tasks, and after-school enrichment programs that emphasize the foundations for building QESST's desired skill sets. Students who participate in QESST precollege educational programs will be uniquely prepared to advance to careers in engineering and science that support the goal of meeting the Terawatt Challenge to power the world's future energy needs affordably and in an environmentally sustainable way.

Methodology: QESST began the project by starting off small. QESST was in need of a classroom to pilot curriculum materials developed by its K-12 coordinator, and the Liberty Elementary District was eager to support the development of its teachers in incorporating engineering design within the science classroom at its newly designated STEM Schools. The partnership began with the K-12 coordinator working with one teacher, in one classroom, at one school.

In academic year two, the K-12 coordinator returned to work with two classroom teachers, at two different schools, to implement expanded and improved curriculum focused on solar energy and the engineering design process. In year two the partnership also expanded to include representation from QESST at family STEM nights at both schools. In year three, QESST will expand its support to multiple teachers in two different grade levels at two different schools. QESST will continue to support the schools at STEM family nights and will add on additional support in the form of an after-school club at both of the STEM Schools. In addition to its work at the schools, QESST also sent a teacher from the

Liberty School District to participate in a QESST Research Experience for Teachers program at the University of Delaware.

Impact/benefits: The primary educational goal of the ERC is to increase the PV workforce, recruiting young people to become leading researchers in academic and industry settings, professionals in the field who install and maintain PV systems, and policymakers and communicators who work with companies and communities to maximize penetration of new technology. This program demonstrates QESST's ground-up approach to educating the next generation of PV leaders. By creating learning experiences that build students' engagement and understanding of solar energy and PV-related topics, QESST is actively preparing students in the pipeline to persist in the PV field.

Evaluation/Assessment: Participants are asked to complete the goal-orientation subscale of the self-report questionnaire, *Patterns of Adaptive Learning (PALS),* before and after the program. Using a five-point, Likert-style response, participants are asked to respond to their perceptions of goal structures in the classroom and their personal achievement goals. In addition, participants are asked to respond to questions about their interest in engineering careers and to complete a pre- and post-content knowledge assessment on solar energy topics.

Sustainability: To make this program sustainable, QESST has carefully taken into consideration the materials that the district has available. QESST tries to provide the district with curricula that can be supported with existing classroom materials. When needed materials are not present, QESST has tried to supply the district with what is needed (i.e., solar modules) so that the activities can be sustained in future school years. QESST has also worked with the district to provide professional development that fits within the schools' existing professional development schedule and budget.

Tips:

- When developing partnerships with the school district, it is extremely helpful to have a contact (professor, coordinator) with an existing connection or history with the school community. This is helpful for understanding how the district works, what its needs are, and how outside programs can fit into the school structure.
- Teacher and administration turnover within the school district can be a barrier to sustaining a partnership.
- School districts are frequently pressed for funds and materials. In order for a project to succeed on a long-term basis, the school/teachers must be supplied with materials necessary to implement the program.
- When doing outreach with the school districts, you will need to work with the school's daily timetable. This timetable can cause a conflict with scheduling, especially with student volunteers, because they are frequently needed at the school during the middle of the day.

4.3.7.2 ***Center:*** Center for Biorenewable Chemicals (CBiRC)
Lead Institution: Iowa State University
Center Director: Dr. Brent Shanks, Dept. of Chemical and Biological Engineering
Name of Program: Precollege education program

Type of Program: Partnership with Des Moines Public School District

Program Synopsis: CBiRC has established a strong partnership with the Des Moines Public Schools District (DSMPSD), the largest district in Iowa, in order to meet the STEM content and pedagogy needs of the district's science teachers. STEM professional development (PD) is offered for K-12 instructors within the school district with the goal of enhancing the STEM curriculum to become inquiry-based. Teachers who complete CBiRC STEM PD become skilled at creating opportunities for their students to think critically and solve problems.

Contact person/website: Dr. Adah Leshem (adah@iastate.edu), http://www.cbirc.iastate.edu/education/precollege/

Dates of Operation/Timeframe: The partnership with DSMPSD began in 2009, and CBiRC offers several summer professional development programs. Each program varies in length (from one to seven weeks) depending on the content. Additional support is provided by working with district PD trainings during the academic school year. Another PD program, Symbi (Iowa's GK-12 program), provides teachers with PD throughout the school year.

Background: A needs assessment survey was administered when CBiRC was established. Based on the results of this survey, CBiRC offered to help middle school and high school science departments become better aligned between grades and schools. CBiRC provided support to create professional learning communities (PLC) for STEM teachers within the schools and across the district. A pilot PLC was created for the science staff in an adjoining high school and middle school building. CBiRC also began to implement PD programs for all middle and high school science teachers as well as elementary school teachers. The emphasis of the PD programs is biorenewables (both fuel and materials), the bioeconomy in Iowa, and "green collar" careers. The PD programs were designed not only to provide STEM content but also to train teachers to modify their curriculum to become inquiry-based, and to include more opportunities for student critical thinking and problem-solving. Finally, CBiRC implemented a GK-12 program in Des Moines middle and high schools. This was a critical addition as it provides students and teachers with weekly interactions with professional scientists and engineers throughout the school year.

Methodology: CBiRC collaborates closely with DSMPSD staff, including the district science coordinator, superintendent, principals, school improvement leaders, and science department heads. Working together with these personnel has created a strong sense of trust and respect on both sides and, as a result, CBiRC PD programs meet the needs of the district. The GK12 program has provided schools, the teachers, and the students with activities and opportunities never experienced before in the district. Many students have had the benefit of a professional scientist or engineer in their classroom every week for two years. We are waiting for further analysis of data collected to assess the impact of the GK-12 program.

Impact/benefits: The close bipartisan partnership developed between CBiRC and DSMPSD allows for all stakeholders to benefit, including school staff, students, CBiRC faculty and graduate students. Honesty and a willingness to make continuous improvements are the keys to a very successful and dynamic partnership. The teachers who participate in CBiRC programs all agree that these are the best PD programs they have ever experienced. CBiRC values all the feedback gained from the evaluation and assessment process and makes every effort to use the feedback to improve the programs

Evaluation/Assessment: CBiRC works closely with Iowa State's Research Institute for Studies in Education (RISE) to conduct regular assessments, evaluations, focus groups, and surveys.

Sustainability: CBiRC is currently working with DSMPSD to engage local industry to support CBiRC precollege efforts.

Tips: The most important practice we have learned is to listen to what the school administrators and

teachers say they want and need. The next most important practice is to collaborate with the district to meet their needs. The third important practice is to be flexible. Mistakes are a great way to learn how to improve. Honesty and humor come in handy!

4.3.7.3 ***Center:*** ERC for Revolutionizing Metallic Biomaterials (RMB)
Lead Institution: NC A&T State University
Center Director: Dr. Jagannathan Sankar, Department of Mechanical Engineering
Name of Program: Pre-College Education Program

Type of Program: Partnerships with K-14 institutions

Program Synopsis: RMB at North Carolina A&T State University (NCAT) has established strong partnerships with Guilford County Schools in the Piedmont Triad of NC for multiple K-12 outreach initiatives (i.e., RET, Young Scholar [YS], and BioEngineering Institute), and with two community colleges, Guilford Technical Community College (GTCC) of Jamestown, NC, and Edmonds Community College (EDCC) of Edmonds, WA, for RET and National Educational Workshop organization. Working with the NCAT School of Education, CEUs are offered for K-14 RET instructors to support their development of inquiry-based STEM modules based on their summer research in RMB labs. Young Scholars work alongside RET and REU participants in RMB PI labs in the summer. In collaboration with RMB core partner University of Pittsburgh (Pitt), NCAT bioengineering faculty offer a week-long summer camp on tissue engineering for high school students called the BioEngineering Institute.

Contact person/website: Dr. Devdas Pai (pai@ncat.edu), http://erc.ncat.edu

Dates of Operation/Timeframe: The programs have been operational since RMB's first summer of operation (2009). The RET and YS programs operate for 6 weeks in summer, and start two weeks after the 8-week REU program. The BioEngineering Institute operates during the last week of these other programs, giving scope for productive interactions among all outreach participants and RMB mentors. NCAT has collaborated with EDCC to organize and support the National Educators Workshop, usually in the fall semester, at various venues, including twice at NCAT since 2008.

Background: The advanced biomaterials research focus of RMB has necessitated the generation of an engineering undergraduate and graduate student population versed in biological theory and methodology, as well as NCAT's traditional physical-science-based engineering curricula—mechanical, industrial, and electrical engineering. Our pre-college education programs focus on pipeline development with an emphasis on broadening participation.

Methodology: The longer duration of the REU program enables those participants to have their lab safety training as well as research orientation completed prior to the arrival of the RET and YS participants and this is a valuable asset that strengthens the teams of research scholars and graduate students who work with teams of participants in the principal investigator (PI) labs. Several professional development opportunities are shared, including safety and ethics training, weekly seminar, and field trips to relevant industrial, academic, and research agency labs in the region. Plus, differentiated professional development is offered, including module development training for RETs and orientation to STEM degree and scholarship opportunities for YS' and campers.

Impact/benefits: In partnership with EDCC, sponsorship and organization of the National Educators Workshop has affected approximately 500 STEM teachers, counselors, and K-12 administrators across the country. The GTCC partnership supports a 2+2 articulation policy to allow engineering AA students to transfer all credits into the corresponding BS program at NCAT. The team approach promotes

communications skills and team-building. Participants of past BioEngineering Institutes and Young Scholars have self-reported direct benefits of the programs in motivating them for STEM-related education—especially engineering and computer science—at NCAT and other four-year colleges. This has augmented the population of diverse students entering and successfully graduating from NCAT's BS and MS programs in Bioengineering, which is an historic first for an HBCU.

Evaluation/Assessment: RMB's Associate Director for Assessment, Dr. Robin Liles, and the education and assessment specialist, work closely with RMB PIs and outreach professionals to conduct regular assessments, evaluations, focus groups, field observations, and surveys.

Sustainability: RMB faculty members are exploring local support options as well as education/outreach funding from the National Institutes of Health (NIH), NSF, and the Department of Defense (DoD).

Tips: Involvement of K-14 personnel in the RMB Educational and Advisory Board provides a conduit for informal feedback from past participants as well as official feedback from these partners to help shape and improve future program offerings. Teaming pre-college participants with REUs and graduate students in the research labs provides for effective two-way learning.

4.3.8 Educational Games

4.3.8.1 ***Center:*** University of Washington Engineered Biomaterials (UWEB), a graduated ERC (1996–2006)
Lead Institution: University of Washington
Center Director: Prof. Buddy Ratner, Dept. of Bioengineering and Dept. of Chemical Engineering
Name of Program: Guy Simplant

Type of Program: Online game-based teaching tool for precollege students

Program Synopsis: UWEB, in collaboration with the University of Washington School of Art, developed a complex and entertaining online simulation aimed at young students. Called "Guy Simplant: The Case of the Ailing Heart," it is a set of interactive games built around the concept of a "special agent" who is battling the forces of darkness in the form of an Evil Spy but who finds he is cardiovascularly impaired.

Contact person/website: Ms. Rita McGreevy (mcgreevy@uw.edu)

Dates of Operation/Timeframe: Continuous online (2002-?)

Background: High school and middle school students often require an entertaining, multimedia approach to spark their initial curiosity about science and engineering. Once "hooked," they can be enticed into further study of science and engineering as their exploration widens and they discover a fascination with various subjects.

Methodology: UWEB, in collaboration with the University of Washington School of Art, developed a complex and entertaining online simulation aimed at young students.

Impact/benefits: The online Guy Simplant simulation provided a means to connect game-playing and entertainment with learning about science, biomedical engineering, and personal health. Thus it provided an effective medium for stimulating interest in science and engineering among young

students, including underrepresented groups, while conveying important knowledge about nutrition and health that will benefit society in the future. The basic concept was developed under NSF funding and the investment from NIH enabled a broader impact. It is also important that K-12 teachers were involved in the curriculum development effort.

Evaluation/Assessment: Not available

Sustainability: With $1.55 million in backing from the National Institutes of Health, UWEB teamed with the Hope Heart Institute in collaboration with Seattle-area teachers to launch a health and science education program built around the Simplant game. The UW School of Art and the Washington Mathematics, Engineering, Science Achievement program (MESA) were also involved.

This initiative, called "Youth Take Heart," is a five-year educational plan focused around cardiovascular health and aimed at students in grades 6–12. The effort has two main emphases. The first is to introduce students, especially minority students, to careers in health and science; and the second is to educate them about good health practices. In the process of helping Guy, students learn how the heart works, what can go wrong and why, and how heart disease is treated. They are asked to set up a program for Guy to manage his diet, exercise and stress, and they have an opportunity to see the results. At the same time, the students learn about tissue engineering and a cutting-edge research project by the UWEB and Hope Heart to grow living tissue to repair damaged hearts. The Youth Take Heart program also included a laboratory kit and general curriculum. The ERC planned eventually to offer it to students across the state and country.

Tips: Not available

4.3.8.2 ***Center:*** Center for Sensorimotor Neural Engineering (CSNE)
Lead Institution: University of Washington
Center Director: Dr. Rajesh Rao, Department of Computer Science and Engineering
Name of Program: WrestleBrainia3000

Type of Program: Informal Outreach Tool

Program Synopsis: In 2012, the CSNE launched the Tech Sandbox Competition, a team activity to develop new student projects using ERC-based research and equipment. The winning project, WrestleBrainia3000 (WB3K), has proved to be an engaging outreach tool and one of the CSNE's greatest education assets. Since its creation, WB3K has been used to reach thousands of students at dozens of informal science outreach events including Brain Awareness Week, University of Washington Engineering Discovery Days, and Life Sciences Research Weekend. WB3K was also selected to represent the ERC program and the NSF at The National Science Fair in Dulles, VA, and the USA Science and Engineering Festival in Washington DC, and was a success at the 2014 Consumer Electronics Show.

Contact person/website: Lise Johnson, liseaj@uw.edu

Dates of Operation/Timeframe: WB3K was developed in 2012 and is still in active use.

Background: WB3K was developed by a team of graduate and undergraduate students in the CSNE as part of the Tech Sandbox competition. It is now owned and maintained by the CSNE, where a new version is in development.

Methodology: WB3K is an engaging two-player game that utilizes electrical signals from muscles to allow users of all ages to play an arm-wrestling game where neuromuscular signal strength, instead of physical strength, moves two intertwined "wrestling arms" and determines the winner. Participants get direct visual feedback about their muscle firing patterns and learn basic concepts about the nervous system and neural engineering. WB3K works by using surface electrodes to detect electrical signals in firing muscles (EMG). Signals from each player are recorded, amplified, and measured against a resting state baseline. Amplified and processed signals between the two players are compared to determine whose signal is stronger and thus which way to move the fuzzy pink wrestling arms. Electrodes can be placed on any muscle group, so participants can be creative in what contests they perform. Smile contests have become a popular variation on the traditional arm-electrode-driven wrestling match.

Since EMG signals depend less on total muscle size than on skin conductance, muscle fiber recruitment, and effort over baseline, smaller and weaker players can compete with larger, stronger players. This means that kids can beat grownups, non-athletes can beat jocks, and anyone who tries hard has a decent chance to win. There are some tricks about contracting and relaxing muscles that can give you an advantage, but you'll have to play to figure them out! WB3K seems to tap into everyone's grade-school fantasy of being stronger than bigger classmates, siblings, or adults.

Impact/benefits: Thousands of people, from elementary school children to elderly adults, have played WB3K at several large events. We expect that thousands more players will try the game in the coming year.

Evaluation/Assessment: WB3K is an informal science outreach demonstration and is evaluated as part of the CSNE's activity at any outreach event.

Sustainability: Version 2 of WB3K is currently under development at the CSNE.

Tip: The demonstration works so well because a) it is competitive, and b) fuzzy pink arms are involved. These two factors really make WB3K more fun for kids and thus a good learning tool.

At the 2013 UW Brain Awareness Week Open House, young students compete at arm-wrestling using CSNE's WrestleBrainia 3000 game. (Credit: Eric Chudler)

4.3.9 Community Programs

4.3.9.1 ***Center:*** Quantum Energy and Sustainable Solar Technologies (QESST)
Lead Institution: Arizona State University
Center Director: Dr. Christiana Honsberg, Department of Electrical Engineering
Name of Program: Community Outreach (University Sponsored Events)

Type of Program: General community outreach

Program Synopsis: QESST has been very successful at leveraging the outreach opportunities provided by large university-sponsored outreach events among the ERC partners. Events such as Arizona State University's (ASU) Night of the Open Door, Houston's Energy Day, the University of New Mexico's School of Engineering Open House, and the University of Delaware's Campus Sustainability Day have allowed QESST to educate teachers, students, and the general community about the mission of the Center and the workings of solar energy.

Contact person/website: Jenefer Husman, Education Director (jenefer.husman@asu.edu), Christi Mendoza, Precollege Education and Outreach Coordinator (christine.mendoza@asu.edu)

Dates of Operation/Timeframe: Participation in these programs began during the first year of the Center. Many of these programs take place annually on our university campuses. The events can range in duration from a few hours to one or two full days.

Background: The primary educational goal of the ERC is to increase the PV workforce, recruiting young people to become leading researchers in academic and industry settings, professionals in the field who install and maintain PV systems, and policymakers and communicators who work with companies and communities to maximize penetration of new technology. Secondarily, the education arm of the ERC is developing outreach programs to improve understanding of solar energy, and demonstrate the importance of finding alternative sources of energy that will reduce our foreign dependence and provide cleaner, sustainable energy. By using large university-sponsored events, QESST is able to work toward advancing these goals in a simple, cost-effective manner. Last year, Houston's Energy Day and ASU's Night of the Open Door each attracted close to 15,000 visitors. Operating outreach booths at these types of events provides QESST faculty and staff with the unique opportunity to interact with a very broad and diverse population.

Methodology: Education and outreach coordinators or faculty points of contact for QESST communicate with university and department officials about university-sponsored outreach events. QESST education and outreach coordinators or faculty points of contact—and in some cases QESST scholars—take the lead in organizing QESST activities for the events and recruiting QESST scholars and faculty for staffing them. QESST education and outreach coordinators and faculty frequently share ideas and resources for outreach activities across the Center.

Impact/benefits: In its first two years as an ERC, QESST has reached 5,818 K-12 students through ERC-sponsored education and outreach events. These events were also attended by 151 faculty/teachers. Through these interactions, we can begin to plant the seed and spark interest in solar energy as we begin to recruit the next generation of solar engineers. It is also an opportunity for us to educate and inform the public about the benefits, myths, and science of solar energy. Through education, we can help to create more informed decision and policy makers.

Evaluation/Assessment: All QESST education and outreach events are tracked using the Project Center database manager, For each event, there is an event description; target audience; number of students, teachers, and community members in attendance; and the number of QESST faculty and students who participated in the event.

Sustainability: By participating in university-sponsored outreach events, the main cost of organizing, promoting and producing the event are covered by the university. After the initial startup, many outreach activities and resources can be used year after year, which reduces the funding needed in subsequent years.

Tips: Staffing outreach events, especially if there are multiple outreach events in a given year, can be challenging. Often you find that students can become burned out because the same few students volunteer for the majority of the outreach events. It is therefore important to build a culture where outreach is valued, and to have faculty who stress the importance of outreach and who support their students' participation in. It can also be challenging to come up with new and novel outreach activities, especially when participating in the same outreach events year after year.

4.3.9.2 ***Center:*** Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks (CURENT)
Lead Institution: The University of Tennessee
Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science
Name of Program: Family Engineering Night

Type of Program: Pre-college, school outreach / community engagement

Program Synopsis: CURENT collaborates with local school systems (elementary or middle schools), local science museums, or Boys and Girls Clubs to host Family Engineering Night events. The family event brings about ten hands-on engineering and science activity exhibits to the schools for students and their families/friends to participate in. Activities may include students practicing engineering communication skills, testing structures like a civil engineer, building a biomechanical hand like a biomedical engineer, learning about electrical engineering concepts like solar panels and generators by racing solar cars, experimenting with momentum as it would apply to a roller coaster like a mechanical engineer, and many other activities. Demonstrations using a plasma ball and other science gadgets are also used to perk student interest. Students are rewarded for participating and completing each activity through extra credit from teachers and a small gift from CURENT.

Contact person/website: Chien-fei Chen (cchen26@utk.edu) or 865-974-3787. More information can also be found at http://curent.utk.edu/news/press-releases/family-engineering-night-at-sequoyah-school/

Dates of Operation/Timeframe: One evening event per year typically runs from 5:30pm to 8pm.

Background: The identified need was to engage young students in fun, interesting engineering or science activities, and to expose them to the field of engineering at an early age. Most important, one of CURENT's educational goals is to tie family engagement to engineering learning by providing support for children to be interested in future engineering study. The concept came from the desire to provide a multifaceted "science fair" that showcases many different fields of engineering. CURENT's family engineering night inspires students to make real world connections with engineering by engaging students with hands-on engineering-related activities with everyday materials.

Methodology: This event may include a pre-event activity, a family event, and a post-event activity, depending on the school's interest and involvement. The pre-event activity could include the introduction of the family night event, engineering fields and careers, and the process of becoming an engineer. In addition, a hands-on project could be designed one week after the family event took place. Post-event activities focus on the extension of this event by teaching students basic engineering concepts through hands-on projects in the classroom.

Collaboration with a motivated science teacher at the school/organization is important. It is also helpful to have flexible school administrators who have a desire for such an event to take place. A variety of engineering related activities should be included. Depending on the household income level of the school, a meal or snack may need to be provided by the school to incentivize families to attend without worrying about the dinner plan. CURENT works closely with one science teacher at each school to organize logistics and select activities. That teacher also recruits other teachers to help with the activity exhibits. CURENT handles material procurement/preparation, flyers/posters, media releases, and pre- and post-event activities. The Center also provides Student Leadership Council and undergraduate students with outreach opportunities by allowing them to be role models for the younger generation. Depending on the amount of support provided by the school, the logistics could be very simple or somewhat challenging. Organizing stations several days in advance and assigning roles to multiple people to assure that each station can be set up in a timely manner without issues are critical to success, as well as having enough people to allow for breaks and to help with any large influxes of people.

Impact/benefits: This program is important for the education community because it addresses the need to increase engineering enrollment among students to keep up with demand in the field. We operate with the idea that if students can see the exciting, impactful, hands-on side of engineering from an early age, they are more likely to view/understand the field in a positive light and invest more effort in

becoming an engineer. In addition, parents/guardians/families being engaged in engineering will provide/enhance support for their children to study engineering beyond the classroom.

Evaluation/Assessment: Post-event surveys among students and parents are used to determine students' learning, interest, and attitudes about engineering. In addition, parents' feedback is evaluated.

Sustainability: Collaborating with schools that have funding set aside for community engagement activities helps alleviate the financial burden. These types of events also provide outreach and leadership opportunities to university students, so they are more likely to voluntarily help facilitate exhibits and transport materials.

Tips:

- Collaboration with local schools or other STEM education teams at the university is helpful.
- Finding teachers with time/availability to act as liaison between the school and the Center is crucial.
- Be prepared to provide incentives for families to attend (food or small item -pencil, notepad, etc.).
- Order and prepare materials far in advance.
- When budgeting, take into account costs for flyers, posters, labor, and additional promotional publications for the school to disseminate to students and parents in the weeks leading up to the event.
- Plan to have helpers that can roam between activities and help where the most people are located. These same people can relieve other helpers so breaks can be taken.
- Each helper needs to have an initial area of responsibility when setting up at the school that began with them helping to prepare the materials in advance.

4.3.9.3 ***Center:*** ERC for Extreme Ultraviolet Science and Technology (EUV ERC), a graduated ERC (2003–2013)
Lead Institution: Colorado State University
Center Director: Prof. Jorge Rocca, Department of Electrical and Computer Engineering
Name of Program: Lighten Up! (Girl Scout Program)

Type of Program: K-12 outreach

Program Synopsis: Workshops for Girl Scouts (ages 11-14) are conducted by the Center's education director based on activities in the workbook "Lighten Up!", which was produced by the Optical Society of America (OSA) for the Girls Scouts in 2007. The workshops are three hours in length and the Scouts conduct hands-on activities on color, the electromagnetic spectrum, and optics using materials provided by the EUV ERC. Kits containing the majority of materials required for these activities have also been donated to each Girl Scout Region so that the Scouts can do activities with their troops.

Contact person/website: Elizabeth Zipse, Grant Program Manager, OSA Foundation (lzipse@osa.org), Kristin Courington, Membership Director, Girl Scouts of Colorado (kristin.courington@gscolorado.org)

Dates of Operation/Timeframe: The program is year-round. During the school-year, workshops are

scheduled in each region and the Center's education director travels to conduct them for 20-40 girls. During the summer, workshops are scheduled on an "as-needed" basis

Background: The Optical Society of America (OSA) created a workbook in 2007 containing activities and information about color, the electromagnetic spectrum, and optics called "Lighten Up!" specifically for the Girls Scouts of America. It also examples job opportunities available in the field of "photonics" and includes several career biographies of women in the field. The target audience for the workbook is girls from ages 11 to 14 (Girl Scout Cadette level, for grades 6-8) and the activities were designed so that the girls could perform the activities on their own, perhaps with some guidance from their leader, using materials that were readily accessible. The education director saw an opportunity to reinvigorate the program by offering to purchase the supplies needed for the workshops and run them. The material in the workbook aligns with the education goals of the EUV ERC and there was no reason to reinvent the wheel! In addition, it provided an opportunity for students at the Center to participate in outreach activities.

Methodology: The EUV ERC requested funds from the OSA to enable the education director to conduct workshops, based on the workbook, for the Girl Scouts of Colorado and to donate materials to each region so that girls could more easily participate in this STEM activity. The education director coordinated with the Girls Scouts of America to schedule events

Impact/benefits: By partnering with the Girl Scouts of Colorado, the EUV ERC has been able to provide this activity across the State of Colorado and raise awareness of STEM content and careers to hundreds of girls. In addition, the materials provided will assure that Girl Scout troops will be able to continue engaging in these activities after Center participation has ended.

Evaluation/Assessment: A post-activity survey is used for girls to provide feedback about which activities they liked or didn't like.

Sustainability: Kits have been created that are donated to each Girl Scout Region

Tips: Finding the right person to coordinate with on joint ventures is key!

4.3.9.4 ***Center:*** ERC for Extreme Ultraviolet Science and Technology (EUV ERC), a graduated ERC (2003–2013)
Lead Institution: Colorado State University
Center Director: Prof. Jorge Rocca, Department of Electrical and Computer Engineering
Name of Program: Osher Lifelong Learning Institute at Colorado State

Type of Program: Outreach to the general public

Program Synopsis: A short course on nanotechnology was developed specifically for the Osher audience, which is adults 55 and older who are interested in maintaining their education.

Contact person/website: Dr. Kaarin Goncz kgoncz@engr.colostate.edu
http://www.online.colostate.edu/osher/

Dates of Operation/Timeframe: Osher offers courses year-round.

Background: The goal of outreach and education spans all age groups and walks of life. Often, the older population is left out of the picture, but it is good for them and good for science and technology to expose them to new technology.

Methodology: The Osher program exists in concert with many universities and colleges. Osher at

Colorado State University was established in 2006, as one of 115 such institutes nationwide. The main Osher office at each institution can be contacted to discuss what program might be most appropriate as well as the best format for introducing the material.

Impact/benefits: This type of program affects an underrepresented population with regards to STEM education.

Evaluation/Assessment: Osher has evaluation and assessment tools in place.

Sustainability: Osher provides a small compensation to its instructors.

Tips: Applications for teaching are due well ahead of the semester, so it is important to keep track of deadlines.

4.3.10 Diversity Programs

4.3.10.1 ***Center*****:** Center for Sensorimotor Neural Engineering (CSNE)
Lead Institution: University of Washington
Center Director: Dr. Rajesh Rao, Department of Computer Science and Engineering
Name of Program: MESA (Mathematics, Engineering, Science Achievement)

Type of Program: Diversity/outreach

Target Population: K-12 students

Program Synopsis: For many years, the MESA Schools Program (MSP) at San Diego State University (SDSU)has combined academic support and out of classroom engagement with industry and alumni to improve the success, retention, and graduation of underserved students studying in STEM (Science, Technology, Engineering, and Math) fields. SDSU MSP is a member of MESA California, one of the country's most innovative and successful programs in STEM. MESA works with thousands of educationally disadvantaged students so they excel in math and science and can graduate with math-based degrees, thus contributing to a talented and diverse STEM workforce.

In 2011 the National Science Foundation funded the ERC for Sensorimotor Neural Engineering at the University of Washington (UW), a collaborative effort with partners MIT and SDSU. From 2011 through mid-2013, MESA was a partner of the CSNE and provided a pipeline of over 2200 diverse students from grades 6 through the undergraduate college level. This pipeline was created from the San Diego MESA Alliance, a collective effort of the five MESA centers in San Diego and Imperial Counties serving K-12, community college, and university-level STEM students from diverse backgrounds. The MESA programs at SDSU and Southwestern Community College (SWC), both Hispanic Serving institutions (HSI), were direct partners of the CSNE.

With the MESA infrastructure in place, dedicated CSNE activities were provided to MESA students, local middle and high school students, and to the general San Diego community to help move students into STEM and to expose them to CSNE fields. These outreach, retention, and success strategies increased the diversity and number of students that enter CSNE-related fields. Activities exampleed here are:

- The prosthetic hand project that we've incorporated to numerous outreach and leadership events (e.g. Leadership Summit, Engineering and Science Festival, etc.)
- Undergraduate CSNE Ambassadors

Contact person/website: Lise Johnson, liseaj@u.washington.edu

***Dates of Operation/Timeframe*:** CSNE activities started in 2011 and ran through mid-2013. Most CSNE activities took place during the academic year.

Background: The prosthetic hand concept was derived from the National MESA Prosthetic Arm competition by the MESA Schools Program Director. Collectively, the SDMA Directors came up with several ways it could be adapted to serve as a portable project for use at various outreach events throughout the city, on or off-campus.

Methodology: The prosthetic hand project requires basic supplies that can be found at craft stores. It can be facilitated in as little as 15 minutes or as long as 6 hours or more. SDMA staff and/or CSNE Ambassadors facilitated the project at various events throughout the year.

Impact/benefits: The pipeline of MESA students in San Diego and Imperial Counties are largely underrepresented in STEM, are first generation college students, and come from low income and/or underserved backgrounds. CSNE activities serve to provide these students with experiences and knowledge of career paths they are unaware of and would not otherwise be able to pursue. These practices also actively engage undergraduate students by helping them to remain and graduate in a STEM major, ultimately becoming STEM professionals who contribute positively to the Nation's economy.

At the NSF site review in Spring 2013, reviewers expressed concern that the MESA involvement was on the one hand too restricted to California and on the other too broad, being statewide, to produce significant impact. Accordingly, the partnership was ended and CSNE began working with Math Science Upward Bound (MSUB), a Washington-based organization that works with students in three local-area high schools. By working with MSUB and by targeting its efforts (including the RET and Young Scholars Programs) to these three high schools, CSNE expects to make a systemic change in the STEM curriculum at the schools.

Evaluation/Assessment: Participants evaluated each activity by completing forms at the end. We found that these activities had high impact on the participants' knowledge of, comfort with, and intention to pursue fields in CSNE and STEM in general.

Sustainability: As a low-cost activity, the prosthetic hand project can be facilitated by MESA during MESA and campus events.

Tips: This work is a collaborative effort among the MESA programs at their respective institutions. Each campus has an existing infrastructure, staff, etc. in place. Without this type of infrastructure, the CSNE would have required a program coordinator and support staff to facilitate these activities. The CNSE-MESA partnership was critical to its support and ultimately provided high impact experiences for students that otherwise would not have been possible.

4.3.11 Young Scholars Program

4.3.11.1 ***Center:*** Center for Sensorimotor Neural Engineering (CSNE)
Lead Institution: University of Washington
Center Director: Dr. Rajesh Rao, Department of Computer Science and Engineering
Name of Program: Young Scholars Program (YSP)

Type of Program: YSP

Target Population: High school students

Program Synopsis: During the summer, the CSNE runs a 10-week Young Scholars Program (YSP). The CSNE hosts approximately five YSP students in UW Center-affiliated research laboratories every year. All participating students are paid a stipend of $5,000. No funds are provided for travel or housing, so participants are expected (but not required) to be local. Laboratories hosting students receive a $500 supply budget and the primary mentors of the students are given $500 to travel to a scientific conference of their choosing. In the summer of 2013 we received more than 70 applications. In addition to being integrated into laboratory research, YSP students participate in a scientific communications class taught by the CSNE education manager. This class is designed to help students develop personal, professional, and career skills and covers topics such as reading and writing scientific journal papers, making scientific poster presentations, preparing and delivering scientific talks, and communicating scientific concepts to lay audiences. Students also attend a series of special seminars on topics such as the responsible conduct of research, industry and intellectual property, preparing for and applying to graduate school, and neuroethics. At the end of the Ten-week program, CSNE YSP students join approximately 100 other students working on summer research projects in other University of Washington (UW) summer programs to present posters about their research at a UW-sponsored research symposium. YSP students also make 15 minute oral slide presentations to members of the CSNE community. Some of the YSP students volunteer to participate in various informal science outreach events hosted by the CSNE.

Contact person/website: Lise Johnson (liseaj@uw.edu), http://csne-erc.org/education/young-scholars-program-ysp

Dates of Operation/Timeframe: 2012-present, summer only (10 weeks), 40 hours per week

Background: As required for all ERCs, the YSP was proposed as part of the Center's original grant and was implemented the first year of funding. The YSP is run in exactly the same way as the REU and the YSP students participate in all of the same activities as the REU students.

Methodology: The YSP is, at this point, funded entirely by the CSNE core budget. The YSP application is posted online in November and is due February 1st. All applications and application materials (essays, transcripts, and letters of reference) must be submitted through our website. The CSNE education staff does a preliminary review of the applications; leaders of labs accepting students are involved in the second round of reviews. Offers are made on March 1st and prospective participants are given one week to respond. Lab assignments are based on mutual interest between the participants and lab leaders and are confirmed by April 1st. Students are put in contact with their mentors before the start of the program so that they can arrange any necessary prerequisites (human or animal subjects training, building permissions, etc.) well in advance of their arrival. Participants are paid every two weeks.

Impact/benefits: The YSP allows young students to become involved in cutting edge research, to see how academic labs function, and to get a feel for what graduate school would be like. This experience can inform their future academic and career goals. The CSNE is focused on increasing the diversity of the next generation of neural engineers and the YSP is one way build the pipeline of underrepresented minorities going into the field.

Evaluation/Assessment: The CSNE contracts with external education evaluators at the Center for Research and Learning for program assessment. These evaluators have designed a post-program survey that they administer to the students. The survey measures the program's impact on the CSNE target skill sets and attempts to capture the participant's perceived benefit and the impact of their program on future educational and career plans. Noteworthy outcomes have included: awareness of career paths, gains in self-confidence, and becoming part of a learning community.

Sustainability: We are investigating grants to support precollege research experiences.

Tips: Because YSP students participate in the same activities as the REU students, they must be exceptionally mature and willing to put forth significant effort. Careful screening during the admission process is necessary to assure that this is the case.

4.3.11.2 ***Center:*** CURENT (Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks)

Lead Institution: The University of Tennessee

Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science

Name of Program: Young Scholars Program

Type of Program: Pre-college

Program Synopsis: CURENT recruits sophomore, junior, and senior high school students from schools within and bordering Knox County, Tennessee to participate in YSP. This YSP operates during the summer and semester terms. The paid summer program typically includes 8-14 students who are mentored by faculty and graduate students. Pairs of students work to explore engineering projects related to the fields of power systems, power electronics, renewable energy, cyber security, materials, and other engineering fields. Students present an oral presentation in front of faculty, graduate student mentors, peers, and family. In addition, they participate in a poster session at the University of Tennessee (UT) STEM Symposium. A technical paper is required to summarize what they have learned. Examples of research projects include smart home energy consumption and grid stability, demand response and power systems, nanotechnology, development of impedance measurements, complementary metal oxide semiconductor (CMOS), electric bike development, micro grid analysis, and social-psychological factors of affecting electricity usage.

Contact person/website: Chien-fei Chen (cchen26@utk.edu), http://curent.utk.edu/education/pre-college/youngscholars/

Dates of Operation/Timeframe: Six-week summer program (9-4pm daily) or once a week during semesters.

Background: Limited research programs have been offered locally to provide high school students with the opportunity to participate in actual engineering design and connect with engineering concepts through real-world projects or learning. This YSP allows students to participate in their own engineering design projects and observe their peers' projects. By interacting with faculty and graduate students, a better understanding of what engineering is and how research is conducted. This program gives high school students a greater perspective about engineering and might enhance their interest in attending an engineering university.

Methodology: The overall structure of this program includes a research project, fundamental knowledge learning, computer programming, and professional training. Starting in the Spring, faculty are asked for potential ideas that would allow the high school students to be guided by graduate students while doing a portion of a larger project, or asked for a project that the student could develop from start to finish. Applications are sent to local science teachers and local county school science departments to promote the program. The applicants are reviewed based upon their past academic achievements and their demonstrated interest in doing research. Upon determining the candidate pool, particular interests are matched with faculty projects. In certain cases, high school students are matched with high school teachers who participate in the research experience for teachers (RET) program. After the students begin the program, a discussion of their projects is held to determine that they are satisfied with the

type of work they will be doing. To further support participants' technical and non-technical knowledge development, seminars across different engineering fields and field trips are incorporated into a weekly schedule. At the end of the program, students submit a presentation, technical poster, and technical paper about their projects.

Impact/benefits: This program uniquely promotes engineering in a way that is not otherwise accessible to local high school students. After this program, most of the participants have shown increased interest in studying engineering and have a better understanding of what engineering is. The confidence of students grows as well as their respect for the highly complex problems that engineers address, of which they were previously unaware. As these students follow their interests, they have a more realistic and positive understanding of an engineer's mission and a more sophisticated understanding of the potential impact they can have on the future.

Evaluation/Assessment: Biweekly interviews by the education director and coordinator are conducted with each student to monitor his/her progress and interest in the program. The director also meets with mentors regularly to discuss students' progress. Pre- and post-surveys are used to determine the students' overall perspective about engineering. A detailed program evaluation by participants is required to evaluate the program structure and determine areas for improvement.

Sustainability: Leveraging with other organizations or county school system is an important step toward sustainability. Several of the projects were coordinated with other groups around the campus. For example, the electric bicycle project cost less than half its normal expense since many materials were borrowed from other organizations. Seeking industry funding either through materials or financial support is a great way to sustain. Seeking STEM grant opportunity is another way to sustain.

Tips:

- A variety of seminars, field trips, brown-bag lunches, and the chances of interacting with university students and faculty are necessary additions to the research projects.
- Recruiting faculty and graduate students who are passionate about education is the essential. Mentors are the important role models in influencing students to study engineering.
- A mentor training workshop is a good method to provide effective mentorship.
- Recruiting high school students in person is more effective than sending flyer or emails.
- Having weekly seminars/classes and weekly deadlines for reporting updates provides students with enough responsibility that they can work sufficiently and feel independent.
- Each project should have multiple tasks that can be worked upon throughout the term.
- Weekly reports about students' projects and seminars help the students stay focused throughout the summer term.

4.3.11.3 ***Center:*** Nanosystems ERC for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT)
Lead Institution: University of Texas at Austin
Center Director: Dr. Roger Bonnecaze, Department of Chemical Engineering
Name of Program: NASCENT Fellows

Type of Program: Young Scholars

Program Synopsis: High School NASCENT Fellows participate in intensive six week summer research and academics sessions. NASCENT Fellows are placed in research teams (two students per team), each team having an undergraduate and/or graduate student mentor, a defined project, and a faculty sponsor. Leading up the summer program, the high school students participate in a week long boot camp where they learn about nanomanufacturing, engineering basics, lab safety, lab tools, ethics, and receive a general campus orientation. They then spend the majority of their time performing original research but also participate in workshops around technical writing, preparing and giving presentations, successful college application, and other life skill topics. In addition, field trips to local nanotech companies and lunches with NASCENT faculty are woven into the curriculum. At the end of the program, the Fellows present posters about their work and experience to a group of NASCENT faculty, graduate students, family, and friends. Student stipend/compensation is provided. Our target audience is high school students, grades 10-12, from underserved groups. Students are typically recruited during their sophomore year and encouraged to participate for multiple summers.

Contact person/website: Risa Hartman (rhartman@che.utexas.edu), www.nascent-erc.org

Dates of Operation/Timeframe: The NASCENT Fellows program is a summer program that launched its inaugural session during the summer of 2013, running from June 26 through August 2. The first summer served as a pilot summer and students participated in a five-week session that ran Monday through Friday, 9:00 am until 3:00 pm. Program length will increase in subsequent summers from five to six weeks.

Background: The United States is losing its leadership in manufacturing, including high tech manufacturing, and needs more qualified engineers and scientists to have a competitive edge. A strong advanced manufacturing base is essential to our global competitiveness and economic, energy, and national security. The goal of the precollege education program is to address this national need by creating a pipeline of diverse, creative students from middle through high school with laboratory research experience who enter college and STEM degree programs. The NASCENT Center developed this program to specifically engage high school students from underrepresented minorities along that continuum in engineering research related to nanomanufacturing.

Methodology: Recruitment for high school students begins during the fall and consists of classroom presentations, dissemination of program flyers, and word of mouth from prior participants. All interested students submit an application by the middle of December. Interviews are conducted with a pool of applicants and final decisions are made that take into account student background, grades, and motivation. Students are informed by February of the decision and are matched with graduate student/faculty mentors based on interests. Faculty sponsor recruitment also begins in the fall. Once faculty commit to the program and determine the research project, they assign a graduate student mentor who then undergoes mentorship training and a general program orientation. Fellows attend a program orientation during the spring where they meet their faculty sponsor and graduate student mentor and tour the facility.

Prior to starting their research, Fellows participate in a nanotech boot camp designed by graduate students and the precollege program director, with input from K-12 teachers. They attend laboratory training, ethics training, and a program kick-off that orients them to Center leadership and research. The precollege program director meets with the Fellows several times a week to gauge progress and offer support/guidance as needed. Field trips, lunches with NASCENT faculty, and educational seminars are offered throughout the session to give Fellows a deeper understanding of nanomanufacturing, engineering, and college life. Fellows attend a poster workshop teaching them specific poster creation/presentation skills and work with their mentor to develop a research poster based on their work. The final day of the program is set aside for a poster session exampleing the students' summer

work. Family, friends, NASCENT faculty/students, and school teachers are invited to the session, followed by a celebration lunch.

Impact/benefits: Laboratory research can be a powerful engagement tool and multiple contacts are more effective than single events in raising awareness and interest in engineering. Consequently, the NASCENT Fellows program examples laboratory practice, multi-level learning teams, and long-term NASCENT affiliation. Benefits of the program can be felt on many levels: Fellows gain a deep understanding of engineering research and its broader implications; mentors gain valuable leadership skills; industry profits from a highly trained workforce; and society benefits from innovative research in cutting edge technologies.

Evaluation/Assessment: The evaluation was designed with two goals in mind: a) provide feedback to program decision makers for improving the program; and b) collect and analyze data to determine whether or not program targets are being met. Additionally, the evaluation plan contains both qualitative and quantitative measures. The qualitative assessment includes surveys and interviews of participating students regarding their satisfaction with the educational program, their perceptions of its strengths and weaknesses, and their suggestions for improvement. Other qualitative assessment examines both sides of the mentor/mentee equation and explores the following areas: a) communication; b) goals and expectations; c) challenges; and d) measuring mentor/mentee interactions. Evaluation measures for mentor/mentee relationships include but are not limited to: a) pre-determined prompts for weekly or biweekly journal entry by teachers and graduate students; b) focus groups conducted in the beginning, middle, and last week of the lab experiences with mentors and mentees to gather data around challenges to the lab experience; and c) quantifying interactions between mentors and mentees using surveys once or twice a week during the course of the lab experience. Quantitative program assessments include metrics on research productivity, student academic performance, and number of precollege participants who go on to attend college. For comparison, the same metrics are determined for a similar mix of precollege students at schools not participating in activities at the NASCENT Center.

Sustainability: The framework for the Fellows program is being written into new NSF education proposals from the university.

Tips: Special attention must be given to the timing of the program. Summer sessions that are too short and do not allow Fellows time to perform substantial bodies of research, while sessions that are too long discourage high school/graduate student involvement. In addition, graduate student mentors must be motivated to work with high school students, as the mentor/mentee relationship is central to the success of the program and the experience of participants.

4.3.11.4 ***Center:*** ERC for Extreme Ultraviolet Science and Technology (EUV ERC), a graduated ERC (2003–2013)
Lead Institution: Colorado State University
Center Director: Prof. Jorge Rocca, Department of Electrical and Computer Engineering
Name of Program: Optics After School (OAS)

Type of Program: Young Scholars

Program Synopsis: High School students from local schools are recruited to participate in optics experiments at the university that are based on experiments from an undergraduate lab course. Students are required to attend four sessions, which are mentored by graduate students. They come back for a fifth visit where they receive a certificate and join in lab tours.

Contact person/website: Kaarin Goncz, Education Director (kgoncz@engr.colostate.edu)

Dates of Operation/Timeframe: This program existed before the Center began and has become an annual event. The workshop occurs in the Spring to coincide with the subject of Optics being taught in High School Physics.

Background: High School students benefit from exposure to experiences beyond high school

Methodology: At the beginning of each year, high school physics teachers are contacted and a date for the Center's education director to visit is set up. At this visit, the education director brings a short presentation for the students describing the EUV ERC and the OAS program. The teacher is left with a sign-up sheet and students must commit to all four sessions. If needed, rides are arranged for the students. Graduate students serve as mentors and one student is usually assigned to a working group (three to four students). Before each session, the students are given a brief lecture on the science content of the lab. The students then perform the labs using a lab book and take lab notes. Students are also informed about our Research Experience for High School (REHS) program and provided with the contact information to apply for this four-week program.

Impact/benefits: All of the students have reported doing better in their Physics class after participating since they are applying the concepts of optics. The other benefit is that students are given a chance to see what the field of photonics is like and to talk with graduate students. For some students, this encourages them to pursue graduate school and all are given more information and are able to make better choices for their careers after high school.

Evaluation/Assessment: A pre- and post-content quiz is administered to all of the Physics students from the high school and a determination of how well students who attended the OAS workshop and those that didn't is evaluated.

Sustainability: This program does not require any additional funding.

Tips: Students who have participated in previous years can serve as ambassadors for recruiting students for the following year. This not only provides the alumni students with valuable leadership and public speaking skills, peer-to-peer communication also facilitates recruitment.

4.3.11.5 ***Center:*** Synthetic Biology Engineering Research Center (SynBERC)
Lead Institution: University of California at Berkeley
Center Director: Dr. Jay Keasling, Dept. of Chemical Engineering; Dept. of Bioengineering
Name of Program: Introductory College Level Experience in Microbiology (iCLEM)

Type of Program: Young Scholars program combined with RET

Program Synopsis: iCLEM is a "learning lab" that consists of eight high school students, two credentialed high school science teachers, two undergraduate teaching/research assistants, and four postdocs who engage in a team-based biofuels research project over an eight-week period each summer. iCLEM students are paid a stipend equal to entry-level service sector work and receive transit stipends, health insurance (if needed), and free breakfast/lunch. Students are selected because of their demonstrated interest in science or engineering. Ninety-seven percent come from low income families with little history of college attendance. iCLEM teachers serve in under-resourced public schools. iCLEM's mission is to motivate, challenge, and equip students to pursue careers in STEM and to involve teachers in research as well as help them translate the experience into classroom curricula and hands-on activities. Equally important, we seek to provide authentic teaching and mentoring experiences for

our postdocs and graduate students.

Contact person/website: Kate Spohr (kspohr@berkeley.edu), http://qb3.berkeley.edu/synberc/iclem.html

Dates of Operation/Timeframe: iCLEM was initiated in 2008. The program runs for 8 weeks, from mid-June to mid-August, Monday through Friday, 9 am to 5 pm.

Background: Before starting iCLEM, SynBERC performed an external analysis of available programs for high school students in the San Francisco Bay Area. We also canvassed a handful of veteran high school science teachers in underserved local communities. We found that, while the Bay Area has an array of science enrichment opportunities, there were no biotech programs targeted specifically for students from low-income families with little history of college attendance. We designed iCLEM to address this need.

Note: SynBERC helped to initiate an international student research competition in synthetic biology called iGEM. In 2011, the iGEM High School Division was initiated with 40 high school teams. See example 4.4.3.1 in the appendix to sec. 4.4 (Undergraduate Education) for more details; also at http://igem.org .

Methodology: The idea and motivation for iCLEM was generated in fall 2007 by two postdoctoral researchers in the Keasling Lab with a vision of engaging a small group of disadvantaged students in state-of-the-art molecular biology research. The idea was presented to SynBERC's director, Jay Keasling, who committed SynBERC funding, staffing, and lab facilities to turn this vision to a reality. Working together with SynBERC's education group, the postdocs mapped out a biofuels-related research project and began creating a rough curriculum. An informal advisory group of science educators was convened to review materials, provide advice and resources, and help with student recruiting. iCLEM was launched in June 2008, with two science teachers, an undergraduate research assistant, and six high school juniors and seniors. Subsequent program refinements included developing a formalized research curriculum and lab manual (2009); adding a College Knowledge component (2010); expanding student enrollment from six to eight students (2011); and adding four postdocs to the instructional team as Science Advisers (2011).

Impact/benefits: Demographics of iCLEM students are 97% low income, 82% underrepresented minorities (URM), 55% English language learners, and 78% from families with no prior history of college attendance. National data for students with similar backgrounds show that only 53% would be likely to attend college. Since inception, 97% of iCLEM students have enrolled in college, and 70% have chosen to major in a STEM field. We have trained 42 students and 19 teachers and teachers-to-be. All teachers trained in iCLEM have created a lesson or unit to translate what they learned in the lab back to their classrooms. Over 1700 Bay Area students are now benefitting from these well-trained teachers each year.

Evaluation/Assessment: Assessments include pre/post program evaluation for students and teachers, weekly student reflections and lab notebooks, and post-program focus groups for teachers, students, and science advisers.

Sustainability: Funding and in-kind support from the Joint BioEnergy Institute, Lawrence Berkeley Lab, the Simmons Fund (a foundation), the University of Califirnia-Berkeley, and government now makes up 92% of iCLEM's budget. We continue to actively seek partnerships and additional funding to make up the remaining 8%.

Tips: Creating and sustaining a high school program from the ground up is no small undertaking. It requires considerable advance planning and a highly motivated team. It is also essential to have a

committed group of stakeholders, community partners, and funders.

4.3.12 Lab Tours

4.3.12.1 ***Center:*** Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks (CURENT)
Lead Institution: The University of Tennessee
Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science
Name of Program: CURENT Field Trip / Lab Tour

Type of Program: Precollege outreach

Program Synopsis: CURENT hosts regular field trips and lab tours for middle, high school students, and senior high school students who have been admitted by the University of Tennessee, Knoxville (UTK). For example, CURENT collaborated with Society of Women Engineers (SWE) at UTK to host a ***Tomorrow's Engineers Today*** event for high school girls from surrounding counties. CURENT collaborated with the College of Engineering at UTK to host a ***Breakfast of Champions*** event for underrepresented students who are high school seniors who have already been accepted to the College. CURENT also hosts a middle school field trip to encourage students to consider studying engineering and computer science.

Contact person/website: Chien-fei Chen (ccne26@utk.edu), http://curent.utk.edu/education/precollege/

Dates of Operation/Timeframe: The program is a one half-day event from 9:00am-1:00pm; students are excused from ¾ of their school day to attend the event. This program is a year-round program.

Background: The identified need was to expose high or middle school students to engineering research and the university setting through fun and interesting engineering visits/activities, and to expose young students to university students who are currently studying engineering. CURENT's goal is to provide a sense of community and communicate the idea that engineering is a dynamic and important field of study. The opportunity of experiencing a laboratory environment and interacting with faculty and university students gives precollege students a more accurate understanding of engineering as a career, which may increase their interest in studying engineering in college.

Methodology: ***Tomorrow's Engineers Today*** was designed for high school girls. The girls participate in several interactive tours of electrical engineering and computer science labs, and attended an engineering student panel discussion to ask questions about the field, college prep, and career options for engineers. In addition, students participate in hands-on engineering challenges (e.g., marshmallow bridge building, solar car design). Collaboration with a student organization is important. SWE provides funding for notebooks, bags, and lunch. CURENT provides the labs, tour guides, recruitment, communication with teachers/schools/parents, and facilities. To recruit participants, CURENT uses our contact with a local county school system to disseminate a flyer to high school science teachers. Students are required to coordinate with their teachers to attend. Students are also required to submit a parental permission form, a photo release form (optional), and a liability waiver. CURENT Ambassadors and SWE student members helped with the discussion panel and hands-on engineering activities. Graduate students introduced their research labs. A similar field trip and tour was designed particularly for middle schools students yearly. ***The Breakfast of Champions*** is designed for underrepresented

students who are high school seniors who have already been accepted to the College of Engineering at UTK. The event includes: lab tours; panel discussion with current students; a lunch discussion with students only and a follow-up with parents only; tours of the engineering facilities; and presentations about financial aid, engineering in general, and student services available to engineering students.

Impact/benefits: This program is important because it addresses the need to increase enrollment in engineering in general, and especially to recruit more women to the field. CURENT operates with the idea that if young students can see the exciting, beneficial, and hands-on side of engineering, they are more likely to view the field in a positive light and invest more effort in becoming an engineer. In addition, the field of engineering would benefit from increased diversity, as women or underrepresented but needed to provide unique perspectives and ideas to the field.

Evaluation/Assessment: A post-activity survey was used to determine students' interest and attitudes about engineering. The Center's education team evaluates the design and structure of the tour and field trip for future improvement.

Sustainability: Collaborating with campus student organizations, Colleges of Engineering, or other NSF-funded STEM centers helps to alleviate the financial burden of these activities, as many groups have funding solely devoted to outreach activities.

Tips:

- Recruit faculty from the entire department besides Center faculty to support the event.
- Finding teachers with time/availability to chaperone for field trips is a challenge. Be prepared to answer a large variety of questions about topics outside of engineering, such as financial aid, admissions, and the university in general.
- Interesting introductions and engaging activities should be included in the tour.
- Graduate students need to be trained to demonstrate and communicate with people who don't have an engineering background.
- It is important to invite engineering faculty member to attend because they are the role models.
- A small give-away item such as pencils is attractive to the young students.

4.3.13 Summer Camps

4.3.13.1 ***Center:*** Center for the Ultra-wide-area Resilient Electrical Energy Transmission Networks (CURENT)
Lead Institution: The University of Tennessee
Center Director: Dr. Kevin Tomsovic, Department of Electrical Engineering and Computer Science
Name of Program: Girls only Adventures in STEM Summer Program

Type of Program: Precollege—middle school girls' weeklong camp

Program Synopsis: CURENT collaborates with the National Institute for Mathematic and Biological Synthesis (NIMBioS) at the University of Tennessee, Knoxville (UTK) to host a week-long day camp for middle school girls. The camp features a variety of engineering, biology, math, and sustainability

activities and projects. Students also take a field trip to various STEM-related departments on the UTK campus, including the Solar House, the College of Veterinary Medicine, and the robotics and artificial intelligent research labs. In addition, students have the opportunity to interview women engineers and scientists. The week wraps up with a poster presentation session in front of families, faculty, graduate students, and staff.

Contact person/website: Chien-fei Chen (cchen26@utk.edu), http://curent.utk.edu/news/press-releases/middleschool-girls-take-an-adventure-in-stem-at-curent/

Dates of Operation/Timeframe: Weeklong summer day camp (9-4, Monday-Friday). Most recently held on June 3-7th, 2013.

Background: A large disparity exists between the enrollment of women and men in engineering programs. The goal of Girls' Adventures in STEM is to engage young female students in fun, interesting engineering and STEM-related activities, and to expose them to the field of engineering. Additionally, CURENT encourages middle school students to have an opportunity to be on a college campus so they can see the opportunities and benefits of higher education from an early age. The concept came from the desire to provide a multifaceted summer camp that allows girls to explore a variety of STEM-related fields. CURENT encourages students to experience many fields so that they can discover a potential field of interest. The girls also learn team building, presentation, and basic research skills throughout the week.

Methodology: Collaboration with another STEM education-related organization on campus is helpful and provides more exposure to multiple STEM fields for all the participants. CURENT uses our contacts with a local county school system to disseminate a flyer to the local science teachers. In addition, local teachers post this information on the school websites and announce it in the classrooms. The Center also uses campus-wide announcements and local newspaper summer camp guides to help spread the word. Applications have been both paper-based and online, and the online application has been the most effective method of getting applicants by far. Students paid a small tuition fee to cover materials, snacks, and a pizza lunch on Friday. Students who were qualified for free/reduced lunch were eligible for a camp fee waiver. Candidates are not accepted by the program until the parent/guardian has submitted the admission packet (including photo release form and liability waiver) and a check made payable to the Center (except for free/reduced lunch applicants). Confirmed participants then receive an agenda, camp rules, and logistical details one week before the program begins. CURENT prepares the curriculum and materials, and we also employ two to three graduate and undergraduate students to help facilitate activities. The daily schedule is split into a morning and an afternoon session, with each of the collaborating organizations teaching lessons of their specialty during their time slot. CURENT designs material on topics such as what an engineer is, static electricity, circuits, conductors/insulators, energy consumption, and energy generation. Throughout the program, students develop components of a micro grid community that is displayed at the end of the term. On the last day, participants present a poster regarding engineering concepts and their final micro grid community projects.

Impact/benefits: This program is important because it addresses the need to increase engineering enrollment among females. CURENT operates with the idea that if young female students can see the exciting, beneficial, and hands-on side of engineering, they are more likely to view the field in a positive light and invest more effort in becoming an engineer. In addition, the field of engineering would benefit from increased diversity, as women or underrepresented but needed to provide unique perspectives and ideas to the field.

Evaluation/Assessment: Pre and post surveys are used to determine students' learning, interest, and attitudes about engineering. A short interview is conducted to evaluate the effectiveness of the

program. Education team also evaluates the overall design and structure of the program.

Sustainability: Four ways to sustain this program including: a) collaborating with other STEM education groups on or off campus can help alleviate the financial burden; b) collaborating with county level or teachers to disseminate the program; c) seeking funding from companies who are interested in supporting girls in studying STEM fields; d) charging a small materials fee from the parents is reasonable to request; and e) seeking grant support from the government agency.

Tips:

- It is important to understand how to interact with middle school students, especially when handling any behavioral issues that may arise.
- Electronics and cell phones should not be allowed.
- Collaboration with other NSF-funded Centers on campus is very helpful.
- Lectures should not be longer than 15 minutes and should be followed by hands-on projects. Hands-on projects are the key to receiving more attention from students.
- It is also important to require a pick-up authorization form so that students are only picked up from the camp by family/friends that are identified ahead of time.
- This program provides outreach and leadership opportunities to university students, so they are more likely to willingly help facilitate activities.
- Having a campus field trip is an affordable way to get the students out of the classroom and into other interesting STEM-related departments and organizations.

4.3.14 Teaching Materials/Museums

4.3.14.1 ***Center:*** ERC for Extreme Ultraviolet Science and Technology (EUV ERC), a graduated ERC (2003–2013)
Lead Institution: Colorado State University
Center Director: Prof. Jorge Rocca, Department of Electrical and Computer Engineering
Name of Program: OWL (Optics, Waves and Light) Kits

Type of Program: K-12 outreach

Program Synopsis: The OWL Kit contains materials and a suggested curriculum, with extensions, for hands-on classroom activities that are aligned with National Learning Standards for Junior High School. The Kits are distributed to teachers and other outreach organizations (e.g., museums, MESA). The Center's education and outreach director personally delivers each kit and spends time with recipients to help them become familiar with the materials.

Contact person/website: Kaarin Goncz, Education Director (kgoncz@engr.colostate.edu)

Dates of Operation/Timeframe: This program has been in operation since the Center began. The schedule of distribution changes based on the needs of the clients. Kits have been delivered individually and in groups at workshops designed specifically for several teachers at once. All of the teachers who participate in the RET program receive one.

Background: Teachers are always in need of materials for the classroom as well as suggested hands-on activities that are engaging. Creating a kit focused on science content that is relevant to the mission of the EUV ERC provided the Center with an invaluable resource. In addition to giving the kit to teachers, the materials and activities can also be used in other Center outreach activities. For example, the Center participates annually at the *Girls Experiencing Science, Technology, Engineering, Math* (GESTEM) conference in Denver, Colorado, providing an activity for over 100 girls using materials and activities in the OWL Kit.

Methodology: The Center's education director collected information about hands-on activities that addressed subjects relevant to students who are interested in pursuing careers related to EUV science and technology. Activities were chosen that correlated with the Educational Standards in Colorado and California because these are the states which are served by the Center. Materials were collected for the activities and test-runs were performed using teachers and students to determine what worked well. A curriculum was created with suggested activities as well as extension activities that could be conducted on the subjects along with web sites for more information. The kit also contains information about the Center and careers in photonics. Teachers are requested to provide feedback about the kit and as a result, the kit and the curriculum have evolved over time.

Impact/benefits: Over 100 kits have been distributed to individual teachers. Since each teacher has impact on over 100 students a year, the overall outcome of this type of outreach is substantial.

Evaluation/Assessment: Teachers provide feedback on how the materials worked in the classroom, what activities they did, how the activities worked, and any other suggestions they might have.

Sustainability: The kits have been funded through independent grants for the past three years. There was a suggestion to try to market the kits, but the Center has not followed up on that idea yet.

Tips: Schools are headed toward a much more standardized curriculum and are adopting a set of activities and experiments for classroom learning. It is essential to have a discussion with the school district science coordinators to determine what type of materials and activities are useful to the teachers.

4.3.14.2 ***Center:*** Synthetic Biology Engineering Research Center (SynBERC)
Lead Institution: University of California at Berkeley
Center Director: Dr. Jay Keasling, Dept. of Chemical Engineering; Dept. of Bioengineering
Name of Program: Biobuilder.org

Type of Program: Interactive online modules

Program Synopsis: BioBuilder is an open-access website for teaching and learning synthetic biology. It is targeted to advanced high school students and early college undergraduates. Lessons are delivered through web-based animations, in-class and laboratory activities, and a community forum for the exchange of data and best practices. The Biobuilder "tech-tinkering" model for science and engineering education fosters hands-on, practical learning, and challenges learners to apply design-build-test principles to biology.

Contact person/website: Natalie Kuldell (nkuldell@mit.edu), http://biobuilder.org/

Dates of Operation/Timeframe: Biobuilder was created in 2007. The website is freely accessible to all.

Background: BioBuilder was created under the direction of Natalie Kuldell, an MIT instructor and SynBERC principal investigator, in response to numerous requests for synthetic biology learning

materials from policy makers, environmental groups, and members of the media needing to know more about the basic biology involved, as well as scientists wanting to know more about engineering aspects of the field.

Methodology: Inspired by successful animation-based educational efforts such as "BrainPOP" and "Adventures in Synthetic Biology," BioBuilder was originally populated with short, animated narratives, mostly showing the interaction between a lab scientist and an excited young learner. Their brainstorming sessions at the whiteboard and in the laboratory teach topics relevant to synthetic biology: "science," "engineering," "technology" and "community". By design, there is no strict story line connecting the narratives so that visitors can explore topics of individual interest in whatever order they wish.

In 2008, SynBERC provided funding to hire an animator and web developer to work with Natalie Kuldell to repurpose "Adventures in Synthetic Biology" into Biobuilder animations and a website. In 2009, SynBERC funded a teacher to help Kuldell develop two lessons aimed at the advanced high school/early college level, as well as a series of "bioprimers" that link to relevant animations and a hands-on activity that corresponds easily to most advanced biology curricula in high schools, community colleges, and undergraduate programs. With SynBERC funding, the same teacher continued to work on the project for two consecutive summers to refine materials and develop additional lessons.

Impact/benefits: BioBuilder has emerged as a "one stop shop" for students to meander through the animations to learn new aspects of the field, and for teachers to find start-to-finish class activities to integrate into their biology curriculum. Data-sharing and discussion are essential for this emerging community. The Biobuilder website has over 2,000 page views per month.

Evaluation/Assessment: Biobuilder has a user contact/feedback page enabling users to give ideas and suggestions on content improvement. Many ideas for program improvement have come via user feedback.

Sustainability: In 2011, Biobuilder incorporated as an independent, non-profit organization, The BioBuilder Educational Foundation (TBEF). Within 6 months, TBEF raised over $100,000 to expand Biobuilder. With the support of a strong board, robust leadership, and funding from corporations and foundations, TBEF is poised for growth and expansion after SynBERC funding ends.

Tips: Getting a long-term project like Biobuilder off the ground requires a strong, committed leader who sees the project as intertwined with his/her career and personal aspirations. The individual must possess not only deep content knowledge and creativity, but also enormous reserves of energy and political acumen.

4.3.14.3 ***Center:*** Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)
Lead Institution: Stanford University
Center Director: Dr. Richard Luthy, Department of Civil and Environmental Engineering
Name of Program: Stormwater Design Challenge in the Ingenuity Lab

Type of Program: Informal education (museum)

Program Synopsis: A team of ReNUWIt students and post-docs collaborated with the Ingenuity Lab at the University of California-Berkeley's Lawrence Hall of Science to develop and implement an urban water design challenge. The challenge was featured on nine weekend days in February 2013, and attracted over 1000 visitors. The Hall plans to add this challenge to their regular rotation.

Contact person/website: Dr. Pam McLeod, Education and Outreach Manager

(pamelamc@stanford.edu), www.renuwit.org

Dates of Operation/Timeframe: The ReNUWIt Challenge was featured on 9 weekend days in February 2013. The design team met six times over the course of the fall semester (2012) to design the challenge.

Background: The Ingenuity Lab Design Challenge supports ReNUWIt's goal to inspire children's interest in water science and engineering. Working with a public science center allowed ReNUWIt to pursue this goal in an informal education setting. Through the collaboration, ReNUWIt students and post-docs also strengthened their leadership, team-working, creativity, and design skills. The challenge itself was based on ReNUWIt's stormwater research. Participants designed and built a portion of city landscape using simple materials and tested their city's ability to retain stormwater, prevent flooding, and capture pollutants, while considering ecological impacts. This collaboration allowed the design team to distill their work down to basic concepts and provided Ingenuity Lab visitors with a relevant, real-world engineering problem.

Methodology: The design team (one ReNUWIt post-doc, three graduate students, Dr. McLeod, a museum educator from the Lawrence Hall of Science, and an engineering education graduate student working at the Hall) met six times to develop the challenge, following an iterative design process. Throughout the process, the ReNUWIt collaborators and the Ingenuity Lab educators played vital roles in assuring the project's success. The engineers were able to instruct museum educators on the engineering and science principles behind the challenge, and the museum educators were able to use their experience with educational development and previous challenges in the Ingenuity Lab to refine the goals of the challenge, manage the logistics of cleaning and reusing the materials, and use the space in a way that was conducive to visitors' experience and learning. In addition, 24 undergraduate and graduate engineering students, including a high proportion of women and minorities, volunteered to serve as experts during implementation with the public. They were trained by the museum educators in teaching techniques.

Impact/benefits: Visitors learned about stormwater, green urban design, and engineering through this hands-on exhibit. Visitor feedback was resoundingly positive, and children displayed understanding of stormwater issues and terminology. Testing and improving their designs helped the children "see" themselves as engineers. The materials and challenge have already been adapted for use by ReNUWIt in a water festival, and will also be adapted for use in a teacher training workshop in summer 2014.

Evaluation/Assessment: Program assessment included evaluation of designer experience, volunteer experience, and visitor experience. The design team completed pre-and post-program self-report surveys. Feedback from volunteers was collected through discussions at the end of each implementation day. Suggestions for improvement were incorporated into the next day's implementation. The total number of visitors was tracked and the average stay time of visitors was recorded. Feedback from visitors was obtained both verbally and through a short anonymous survey available on a computer near the door to the room.

Sustainability: The Ingenuity Lab has all of the materials associated with the design challenge, and can run it independent of involvement with ReNUWIt.

Tips: It is important to test all materials ahead of time, before implementation with the public. It should also be recognized that some types of design challenges (including the one developed in this collaboration) require a significant amount of facilitator engagement and training to function well.