4.4 UNDERGRADUATE COMPONENT (CORE STUDENTS, REU, COMMUNITY COLLEGES)

Although there are significant expectations for ERC education programs, there is a degree of local variation among centers. This variation arises naturally from the differences in center structure and composition. There are however, underlying similarities in what centers offer undergraduate students. This section will describe the similarities as well as the differences.

4.4.1 Core Students, Academic Year Research

Academic year core students are from the center's lead and core-partner universities. Integrating undergraduate students in the educational activities of ERCs is mandatory, and is perhaps the single most innovative aspect of the ERC education programs. While the research focus and educational vision of ERCs may differ, active involvement of the undergraduates in research has a major impact, not only on their education, but also on those around them. A special feature of the ERC Program is the emphasis on undergraduate participation in research. This is an excellent way to integrate center research into the undergraduate curriculum. Each of the ERCs has one or more programs through which undergraduates from the center's home institution(s) engage in research projects. See appendix section 4.4.2 for examples.

Including undergraduates in center research is the responsibility of all of the center's partner institutions. Undergraduates become part of a center research team and may be paid a stipend or enrolled in credit as determined by each center and institution. A minimum ratio of 1:2 undergraduates to graduate students is required. These core undergraduates are joined by ERC Research Experiences for Undergraduates (REU) visiting students in the summer. (See appendix sections 4.4.3, 4.4.4, and 4.4.5 for examples.) However, it is important to note that these two types of students conducting research are distinct groups for ERC reporting, assessment, and database purposes.

A critical component of the undergraduate research experience is the mentoring that the core undergraduates and REU students receive. Mentoring relationships for undergraduates involved in ERC research may involve faculty to undergraduate, staff to undergraduate, graduate to undergraduate, and undergraduate to Research Experience for Teachers (RET) participants and precollege Young Scholar (YS) students.

Mentors should be carefully identified, with plenty of time allowed for student assignment and mentor training. Being a successful mentor is not an innate characteristic. Therefore, training is imperative. Mentorship training should include everyone involved in the Undergraduate Education program (e.g. faculty, core graduate and undergraduate students, and staff). Training can take place through workshops, seminars, and via podcasts. Suggested topics could include "What is mentoring?," "Why is mentoring important?," "What are the different mentoring relationships in an ERC?," and "What constitutes a "good and bad" mentoring experience?" Importantly, specific "Do's and Don'ts'" related to each program should be clearly addressed. Undergraduate and REU mentor training should be done at the same time. Mentoring is a responsibility of all the partner institutions. See appendix sections 4.4.1.1, 4.4.2.3, and 4.4.3.1 for examples.

To create cohesion of the center's undergraduate researchers, they should be involved in the ERC's Student Leadership Council and should also participate in the NSF site visits and annual retreats.

4.4.2 Recruiting Methods

Undergraduates may be recruited through presentations at student organizations such as the student chapters of professional societies like the Institute of Electrical and Electronic Engineers (IEEE), the American Society of Mechanical Engineers (ASME), the American Society of Civil Engineers (ASCE), the American Institute of Chemical Engineers (AIChE), and through organizations like the Society of Women Engineers (SWE) and the National Society of Black Engineers (NSBE). Non-technical student organization groups may be approached to recruit for specific centers, depending on their mandates. They may also be recruited through announcements in the student newspaper, the ERC's website, printed flyers, and directly from classes and colleague’s recommendations. Also, deans and departmental and other university offices may be helpful. Additional mechanisms such as Introduction to Engineering courses (cornerstone) and design courses (capstone) should be considered for recruitment. Participation in internal undergraduate research symposia and leveraging existing formal undergraduate research opportunity programs are also avenues of recruitment. Outeach by undergraduates to precollege schools, especially high school students, can be an important form of recruitment (see appendix section 4.4.11). Participation in contests and symposia relevant to the center’s research is another option. See appendix example 4.4.6.1.

ERCs are national leaders in including students from underrepresented groups in engineering in their programming, so there is also a strong emphasis on recruiting undergraduate students from a diverse population, including women, members of underrepresented minority groups, those with disabilities, transfer or dual-degree students, and students from post-secondary technical schools and community colleges. These students may be from the engineering disciplines most prominently represented in the center, or may be studying other fields. Thus, undergraduates who are majoring in physics, chemistry, social sciences, education, and business can be valuable and productive participants. Please note, however, that packing the undergraduate population of an ERC with non-engineering students does not meet the ERC Program’s goal of preparing undergraduates to pursue advanced engineering degrees or work as engineers in industry at the B.S. level.

centers should always monitor the diversity of the students who join the center. If the center’s group of students is not meeting the center’s diversity expectations, it is recommended that a survey of current underrepresented students at the center be conducted to see how they became involved with the center. This information may help the center to develop additional recruiting plans that will broaden the diversity of the undergraduate student group. See appendix section 4.4.10 for examples of programs to increase diversity. Example 4.4.8.1 describes a program aimed at recruiting students with disabilities.

4.4.3 Curriculum Development

Developing an ERC education program is a major undertaking, requiring substantial coordination of many faculty from different disciplines. The faculty involved in developing the ERC may already have a vision for new interdisciplinary courses or even a new degree program that can help achieve the Gen-3 ERC requirement to educate engineering students to be globally aware innovators and entrepreneurs. To that end, the ERC can help solidify the interactions that lead to course development and administration. The role of the ERC education program is that of a catalyst; the resources provided by NSF are small compared to those needed to develop and to maintain an entire academic program. Still, the catalyst serves an essential role, and there are examples of ERC education programs that have provided the necessary impetus for creation of new degree programs. (See appendix section 4.4.1.2, for example.) Degree programs may start as minor degrees, specializations, concentrations, or certificate programs and then evolve into new B.S. degree programs as the academic infrastructure grows through addition of resources from outside the ERC. The role the ERC plays in developing new degree programs at an institution depends strongly on how intellectually developed the field already is at the time the ERC is funded. If the area is new and just evolving, the ERC may lay the foundation for development of a program that comes to fruition in the latter years of the center, whereas if the ERC is funded in an area where faculty members are already offering interdisciplinary courses, a degree program may evolve more quickly.

New degree programs require substantial long-term institutional resources and commitment. Institutions have a responsibility to ensure that students are well prepared for life after the degree, and thus typically want extensive intellectual justification for how new programs will allow students to adapt to jobs in industry or academia. Before embarking on new degree programs, it is essential to arrive at a consensus of stakeholders as to what the expected outcomes of such a program would be. This process will facilitate the adoption of any new program developed. Appendix section 4.4.1.1 provides an overview of this process.

Courses (e.g., new courses, short courses, modules for ongoing courses, senior design)

A very important role of the ERCs is to enrich the core curricula in engineering through course modules for ongoing courses and new courses, particularly interdisciplinary and systems-focused courses. These courses will enrich the engineering curricula and also may provide the intellectual basis for a new degree program.

Developing new courses and/or materials for inclusion in existing courses is the first step toward integrating the ERC's research findings into the formal education process and is a key requirement for all ERCs. As a first priority, centers should look for opportunities to add modules, problem sets, and lectures to existing courses, to create relevant online content (non-course format), or to incorporate work in capstone design or similar courses to further integrate center research into the existing curriculum. This is an important means for ERCs to contribute to engineering education in a broader way, as insertion of new materials in ongoing courses does not require the levels of approval required for new courses. The bar is lower, the overall impact is higher, and center research advances can be leveraged more time-efficiently into the curriculum. The beta test approach is important here as well.

The philosophical and administrative aspects of new course development vary widely from institution to institution. At some institutions it may be possible for an ERC staff member to serve as the primary driver. At other institutions, faculty members serve in this role. Ultimately, the university is responsible for paying faculty to teach the course, and for providing additional infrastructure if the course is a lab subject. Thus, courses must fit the overall educational objectives of the degree programs at the institution.

ERC non-faculty staff, in developing undergraduate and graduate courses, should find the following tips helpful:

- Find an interested professor to be a champion for developing the new course.
- Pay the professor and a student helper to develop the course; or arrange with the professor's department chairperson to give the professor a teaching load reduction so that he/she can have protected time to develop the new course.
- Beta test course materials.
- Work on mechanisms to offer credit for students to take the course at the other ERC partner universities.
- Find a vehicle, such as a website or book, for wider distribution of course materials.

In institutions where ERC faculty have this responsibility, they can take advantage of these suggestions, which build on years of hands-on experience in many ERCs:

- Discuss your idea for a new course with your department head or undergraduate curriculum committee. If the new course is an elective in a hot field and you can demonstrate that students will flock to this course, the department will likely be supportive of your plans to develop it. For untenured faculty, development of a signature course can be a very positive factor in your promotion case.
- If preliminary discussions are positive, determine whether you will be provided with long-term support for teaching the subject. Developing a new course requires a great deal of work, so one should make sure it can be taught several times.
- Find a mechanism for supporting your time in developing the course, and for providing appropriate support, such as teaching assistants. If there is no textbook available (likely), course development requires a substantially greater investment of time than teaching an established course does. Foundation and government grants are available for new course development, and funding opportunities can be identified by asking colleagues. Reach out to an center for Teaching and Learning, if one exists at your institution.

Appendix section 4.4.1.3 provides an example of undergraduate course development.

Degree/Certificate Programs

Minor degrees or certificates give students the opportunity to develop depth in areas outside their major degrees. The rules for offering minors, as well as student participation in minor programs, vary widely from institution to institution. At some schools, interdisciplinary minors are a means to evolve the curriculum toward a new undergraduate major by providing a testbed for courses and for development of student professional societies. If the center is in a cutting-edge research area and students are excited about a minor degree in the area, chances are that it can develop a successful minor even if there are institutional barriers. The key is to build on student interest and enthusiasm. Here are some important considerations:

- Define the intellectual content of your minor first —What is essential for the students to learn, and how many subjects are required? Are there subjects already offered that could fit the minor, or do you need to develop several new courses?
- Determine which academic unit is the best home for the minor, whether it be a single department, a pair of departments, a school or college, or the whole university. An academic unit will be required to handle the administrative details if the minor appears as a degree designation, and the academic unit involved needs to be extremely supportive of the minor.
- The easiest minor to develop is for students from one's own school (e.g., engineering), because those students are likely to have taken the prerequisites (e.g., mathematics, programming skills, and biology) needed to take the more advanced courses in your minor. Some academic institutions have firm requirements that any student should be able to complete any minor, and you must be cognizant of what your institution requires.
- If you develop a minor for a cross-disciplinary student audience (e.g., including both science and engineering majors), it is helpful to define a set of preparatory engineering subjects that provide the necessary background for non-engineering students. For example, non-engineering students may need to take Differential Equations and a mainstream sophomore-level engineering subject that uses differential equations to solve physicochemical engineering problems before they can enroll in the subjects in your minor. Alternatively, courses can be developed for non-majors, but this is usually a less attractive option over the long term. Engineering faculty are generally reluctant to develop a course for students who do not have engineering backgrounds, and cannot justify teaching such courses when teaching assignments are made.
- The minor should be well coordinated with the curricula of the major degrees. One must put appropriate advising in place to ensure that students are able to plan early in their academic careers to fit all the minor subjects into their schedules. It is helpful, for example, to write up a special advising document for freshmen and sophomores, to ensure they take appropriate background subjects early on. Conduct advising seminars once per term to get the word out to a broad audience.
- A minor degree curriculum, no matter how well planned, does eat into the unrestricted electives available to students. Some students may even overload on subjects in order to complete the minor. It is thus especially important to have good advising—students must appreciate that the minor is in some sense an Honors program if it requires substantial technical work. It is a choice the student makes. Students who are weaker academic performers might be encouraged to focus on their majors first.
- Create a curriculum committee that meets regularly to review the content and administration of the minor, and invite all the advisors for the minor to serve on the committee.
- Create a community of students involved in the minor by having lunches with students and faculty once per term.

New bachelor's degree programs must be developed with a different set of considerations in mind:

- The academic affairs office MUST be involved from the beginning when considering creating or modifying a new degree (minor or major) or anything that affects undergraduate student credits. They are responsible for shepherding the degrees through governance.
- Find out what new degree program in engineering or science was most recently approved at your institution, and use that program as a benchmark. Some institutions are conservative and develop new degree programs only once every few decades in response to new disciplines.
- The faculty who teach the courses and who will be responsible for the degree program after the center's NSF funding expires must be key drivers in developing the new degree program. Be sure to get the support of key faculty members, who can provide sustained efforts to convince the Chair, Provost, curricular committees, and other decision makers.
- Identify the constituencies for your program, and make sure you have enthusiastic buy-in. Equally important, identify any other academic programs that will be significantly affected (positively or negatively) and discuss your plans with the faculty involved. For example, if you are developing a program that depends on core science classes offered by another academic unit (such as chemistry, math, biology, or physics), they need to be involved, especially if their enrollments are likely to increase as a result of your plans.
- Make sure to contact your university's appropriate office (e.g., the Provost) to find out what approvals are required for a new undergraduate degree program. There is no point in developing an entire program if it will not pass this first hurdle.
- Work as closely as possible with the Chairperson of your school's curriculum review/approval committee, as well as your university's Undergraduate Curriculum Committee, before submitting all of the paperwork to those committees, to be sure that they buy into your new program. Doing so can save a lot of time in getting your new program approved, because these committees frequently deny or delay approval due to incomplete forms or unclear descriptions.
- Involve undergraduates in developing the new curriculum, to understand their interests and needs from the outset. This can be accomplished by presenting a proposed curriculum at a meeting of the professional society for the area related to the program. While some universities require participation by undergraduate students during the development and evaluation stages of your new program, it's a best practice to include undergraduates, whether it is a requirement or not. Neglecting undergraduate input can cause very long delays in getting the new program approved.
- Be sure that your program satisfies criteria of the Accreditation Board for Engineering and Technology (ABET), if one of your goals is to have an accredited program. Review and update this program on a regular basis.

4.4.4 Collaboration with Industry

Industry is involved in all aspects of the ERC's education programs. Industry representatives may serve as mentors to undergraduate, outreach, or graduate students. (See appendix section 4.5.3.1.) They may present lectures, course sections, or entire courses, provide input into the curriculum, or teach courses in partnership with ERC faculty members. Industry experts may serve on the student's masters or doctoral committee. Industry may sponsor undergraduate or graduate internships in industry (see appendix section 4.4.9.1 for an example), or sponsor students' undergraduate or graduate degrees in whole or in part. It is important to allow undergraduates to participate in Industrial Advisory Board (IAB) meetings and interact with industry through social media for networking opportunities. (See, for example appendix section 4.4.1.3.) These experiences provide them a window into industrial practice, and for those who wish to pursue industrial careers after obtaining the B.S. degree, involvement with industry often leads to job offers, due to the richness of the ERC experience. ERC Program-level evaluations have found that industrial supervisors of ERC alumni find them more effective in industrial practice than their single-investigator trained colleagues.[1]

[1] SRI (2004). The Impact on Industry of Interactions with Engineering Research Centers. (http://erc-assoc.org/sites/default/files/studies_reports/Impact%20on%20Industry%20of%20ERC%20Interactions_SRI_12-04.pdf)

ERC Best Practices Manual Chapter 5, “Industrial Collaboration and Innovation,” has a section 5.3.5 on involvement of industry with the ERC education programs.

4.4.5 Evaluation and Assessment

The need and scope for program evaluation and assessment varies based on an ERC’s education program objectives. It is suggested that a person with experience in program evaluation and assessment be identified and used.

An important component of ERC education program assessment is tracking graduates. Follow-up with former students extends the influence and value of the Undergraduate program and contributes to the participant’s involvement in engineering careers and the continuation of their education toward advanced degrees. Former participants can be provided with guidance and assistance with applications for graduate school and for financial aid. Arrangements can be made with the center’s industrial partners to assist participants with potential employment opportunities. Maintaining contact with graduates requires considerable effort, but it increases the likelihood that they will continue on to graduate engineering education. Learning of their accomplishments is also rewarding. Social media such as Facebook or LinkedIn can be useful in this effort.

4.4.6 Research Experiences for Undergraduates (REU) Program

ERCs are required to offer a Research Experiences for Undergraduates (REU) Program. This provides a mechanism to extend the integration of center research to students who would not otherwise have the opportunity to conduct this type of research on their home campus. An REU program also provides an opportunity to diversify their undergraduate student population, but cannot and should not be the only diverse group of students involved in center research. These programs can also serve as a fulcrum for leveraging support from other sources, including industry. The programs go considerably beyond the traditional research-focused mandate of university research centers. Indeed, they place a substantial demand on the administrative and financial resources of ERCs. For example, the ERC must allocate a minimum of $42K to its REU program from core funds and may seek an REU Site Award to supplement that effort. However, the center’s REU Program is part and parcel of the broader mandate to develop a new and more industry-focused, product-focused culture for academic engineering and to spread that culture through education. In that sense, then, "outreach" to REU students is simply extended ERC education.

Appendix section 4.4.3 provides a number of examples of REU program planning and operation at several ERCs. Section 4.4.5 gives examples of REUs involving community college students.

REU Program Features.
Students gain many benefits from their ERC REU experiences that are not normally available to their peers who are not involved in ERC education programs. REU students:

- Conduct individual or team research on ERC-related projects
- Develop teamwork skills through interaction with undergraduates, graduate students, and faculty
- Are encouraged to continue their education in graduate engineering programs
- Develop communication skills through written reports and oral presentations
- Participate in ethics and professionalism activities
- Interact with students from other universities
- Publish articles on research or give research presentations at national conferences
- Participate in industrial interactions
- Become involved in mentoring RET teachers and or Young Scholars
- Interact with a truly diverse group of students.

REU Program Structure.

REU students may work as individuals or in teams, which may include the ERC's own summer undergraduate interns and even graduate students. The students' projects should include at least some elements of their own design and should be supervised by ERC faculty and graduate students. In many cases this environment provides first-hand knowledge of how industrial research teams operate. The total number of undergraduates involved in these summer projects from all sources at a given ERC can vary from as few as 4 or 5 to as many as 40 or 50. Some multi-site ERCs may have only a single REU program, so teaming with local students is vital. The mix of backgrounds, cultures, and approaches brought by students from different educational backgrounds is an important part of the REU experience. See appendix example 4.4.4.1. In addition to research projects, a well-rounded program of REU activities can include:

- Field trips to industrial sites
- Workshops on technical writing and public speaking
- Seminars in topics such as programming and engineering ethics
- Meetings with high school students visiting the campus
- Mentoring by graduate students and industrial residents
- Assistance with graduate school admissions applications and scholarship materials
- Exposure to an array of center publications
- A showcase to present the student's research project at the end of the summer program

Issues that require special planning include housing (prearranged and on campus in the same area), meal cards or subsidy for meals (to minimize the need for cash), on-campus transportation if needed, and access to institutional facilities. Careful scheduling of out-of-laboratory activities is also necessary to minimize research disruptions.

Recruitment Methods

Recruitment of REU participants can be challenging, since the main focus is on underrepresented populations, and the number of programs aimed at these populations has expanded, so there is keen competition for the best students. The ERC REU program has provided a critical outreach component to ERCs, giving them the opportunity to extend their work to many other institutions. Recruitment techniques that have proven successful include:

- Personal visits to other institutions
- Development of long-term relationships with Historically Black Colleges and Universities, Hispanic Serving Institutions, and other targeted underrepresented Minority-Serving Institutions
- Recruitment efforts by previous REU participants on their home campus
- Recruitment through national organizations (e.g. NSBE, AISES or SWE)
- Use of Women in Engineering (WIE), Minority Engineering Program (MEP) and offices that provide services for students with disabilities
- Participation in career fairs
- Internet postings
- Sharing of information about potential participants among ERC Education Directors/Coordinators across the ERC network.

As centers mature, they interact with other ERCs to help them recruit REU fellows for appropriate research areas. This exchange of applicants has been done on an individual basis, from Education Directors/Coordinators to Center Directors, and (in the past) via an e-mailed ERC Education Digest. Given the strong emphasis on recruiting REU students from a diverse population (i.e., women, members of underrepresented minority groups, students with disabilities, transfer or dual-degree students, first-generation students, and students from post-secondary technical schools), centers must develop/leverage connections with schools that serve these populations. Students may not be from the engineering disciplines most prominently represented in the center, and may not even be engineering majors. Undergraduates majoring in physics, chemistry, biology, social science, and business may be valuable and productive REU participants. Because of the burgeoning REU programs, the competition for top students obtained from traditional sources is intense. Broadening the applicant pool can help to achieve diversity while retaining high standards, thereby attracting a new pool of students to engineering. Diversity conferences such as SWE, Society for Hispanic Professional Engineers (SHPE), NSBE, and

Society for Advancing Hispanics/Chicanos & Native Americans in Science (SACNAS) are effective mechanisms for recruitment. Centers have coordinated to co-host "ERC booths" at such conferences. This allows for greater visibility and leveraging of funds (i.e., doing so drastically lowers the cost for individual centers to participate).

REU programs may also benefit from linking with other internship programs on campus. This may allow for supplemental workshops, an expanded cohort, more diversity, and a comprehensive showcase of research projects at the end of the summer programs. One example transition program that uses research as a vehicle to introduce a diverse group of students to STEM is the ELeVATE program at the Quality of Life Technology ERC (see example 4.4.7.2). This program promotes military veterans' transition to campus by linking them with research projects and mentors to help them develop technical skills. Due to shared goals, the ELeVATE participants benefit from the REU program activities and *vice versa*. At the end of the summer, students from both programs can present their research in the same research showcase/forum. This is just one example of the type of program that a center could collaborate with across its campus.

A very effective recruitment strategy is to provide opportunities for Student Ambassadors (past summer interns) to recruit future participants at the target institutions:

- Set up information sessions and workshops
- Present research at information sessions and workshops
- Serve as guest speaker or panelists for information sessions and workshops
- Assist peers with application process
- Recommend peers for future summer internships.

Strategies for Funding

One of the best ways to leverage funding and to improve the efficient use of a center's resources is to join with others in setting up and implementing projects. Once the fixed costs have been met, additional participants bring down the cost per participant and provide cross-fertilization of expertise. A number of ERCs combine REU programs with other programs or funding sources. The availability of supplementary funding allows field trips and extended travel to be included in the students' experience. Many campuses host multiple REU programs and this provides opportunities to co-host ethics and communications workshops, social events, and seminars to the mutual benefit of all of the participants. Also, the considerable expense involved in long-distance relocation has been a barrier to some gifted students, and supplementary funding can be helpful. Again, the best sources of specific information about funding opportunities for attendees are the center websites, and the websites of universities and other centers provide opportunities for co-funding of programs. Providing an interesting research, cultural, and social program for the group requires planning and supervision, but the wide availability of campus facilities in the summer facilitates this process.

Mentoring

Mentoring is a strong component of the success of REU students within ERCs. Mentoring roles for REU programs may involve faculty to REU, staff to REU, graduate to REU, existing core undergraduate student to REU, and REU to RET and Young Scholar participants. Mentors should be carefully identified with plenty of time for student assignment and mentor training.

As was noted in section 4.4.1, being a successful mentor is not innate to all. Therefore, training is imperative. Mentorship training should include everyone involved in the REU program (e.g. faculty, graduate and core undergraduate students, staff).

Given the geographic distribution of the partners of most ERCs, special attention should be given to methods to connect student REU participants at multiple campuses represented within an individual ERC. It is recommended that no less than two students be located at a given institution, to avoid isolation. Additionally, web-meeting software can provide a mechanism to support weekly research discussions of the group. One face-to-face meeting of the group, either at the outset to introduce participants and facilitate web communications, or at an end-of the summer research poster session, is recommended.

Evaluation, Assessment, and Follow-up/Tracking

The comments made in section 4.4.5 apply both broadly and also specifically to REU programs. It is recommended to create REU cohort groups that allow messaging to the group and generating discussion among previous participants, allowing them to stay in touch with each other.

REU Lessons Learned

1. Use multiple methods to recruit diverse students into your programs.
2. Be highly inclusive – leverage resources at your university (e.g., other REUs, honors programs, etc.), and at partner universities.
3. Create strong two-way relationships with your industry membership.
4. Search for ways to create community – find a way to showcase undergraduate research results.
5. Mentoring is important; so train your mentors explicitly.
6. Assessment and evaluation are absolutely critical, and it is highly recommended that you partner with professional A&E teams (internal or external) to develop the A&E strategy for your center. You both need to establish the research questions, as well as ensure that the instruments and analyses will allow you to answer the questions (this includes getting human subjects clearance so that you can publish your results).
7. REUs must be U.S. citizens or green card holders

4.4.7 Community Colleges

The Nation's community colleges and technical institutes are valuable and often underused sources of technical workers. Community colleges serve a vast number and diverse population of students. Due to the flexible scheduling, modest cost, and other reasons, community colleges also attract large numbers of women and minority students. It is estimated that half of the Hispanic students attending college nationwide are at community colleges.[2] For these reasons, they are a fruitful and underutilized source of REU students (see appendix section 4.4.5).

In addition, many community colleges have historically close ties with industry. Industry-oriented or industry-sponsored certificate courses and technical training programs are often associated with community colleges rather than four-year colleges. The technicians and skilled workers of the technology industries are likely to be products of the community college systems.

For these reasons, ERC education programs should actively focus on creating links with community colleges. Again, Academic Affairs offices can help; they are resources to try to connect with and/or utilize any existing articulation agreements and partnerships. Strategies to develop such links may include:

- Provide speakers and guest lectures for community college classes, conferences, and events;
- Provide hands-on demonstrations and activities for community college classes, conferences, and events;
- Serve as an advisor or thought partner on STEM curriculum, proposals, transferring to 4-year institutions;
- Organize interested graduate students and postdocs to volunteer as judges for STEM activities and events at community colleges;
- Partner on grant proposals with community colleges, or provide letters of support for proposals submitted by community colleges; and
- Inform community colleges of STEM events at your campuses

Recruiting

A variety of methods are recommended for recruiting community college students. A starting point is to build a relationship with an academic leader (e.g., department head or program chair or senior faculty

[2] See http://www.highereducation.org/reports/pa_at/index.shtml

member) at target institutions. These people can provide invaluable advice on how best to reach their students.

Recruiting should be viewed as a year-round effort involving active, ongoing communication and interaction at target institutions. For example:

- Invite prospective students to STEM events at your campus;
- Attend conferences and other events that focus on the targeted population and follow up with community college representatives and students you meet;
- Host summer internship information sessions for students at community colleges;
- Host virtual information sessions and workshops through online webinars; and
- Send monthly emails to key staff/faculty contacts and student e-lists with opportunities, updates, and reminders.

Organizations or groups that can leverage your efforts include:

- MESA (Mathematics, Engineering, Science Achievement) is nationally recognized for engaging educationally disadvantaged students so they excel in math and science and graduate with STEM degrees. MESA partners with all segments of higher education as well as K-12 institutions. See appendix 4.4.10.1 for an example.
- Veteran's offices.
- Transitional programs (e.g., 2 + 2) are a powerful way of bringing community college students into 4-year research-oriented institutions. The maturity of such programs varies greatly state-by-state and therefore developing such opportunities will be highly variable amongst centers.
- Your campus' transfer office (if you have one).
- Advanced Technological Education (ATE) centers are NSF-funded centers that endeavor to strengthen the skills of technicians, whose work is vitally important to the nation's prosperity and security. In ATE centers and projects, community colleges have a leadership role, and work in partnership with universities, secondary schools, business and industry, and government agencies, to design and carry out model workforce development initiatives. Given the complementarity of the ATE and the ERC mission, ATE centers may represent a viable location for outreach to community college communities by the ERCs. Please note: The location and subject matter for each ATE center varies by geographic location, so the opportunity for development of connections between ATE centers and ERCs will be highly variable.

Mentorship & Training

Community college students may require additional mentoring to ensure success when involved in summer-research programs populated primarily by students from research-intensive institutions. Take steps to ensure mentors are well trained, and consider doing "boot-camp" or similar orientation/immersion programs to help these students adjust. Community college students are likely best served by experiences within a cohort. Therefore, we discourage sending these students to partner sites where a cohort does not support them.

Other Activities

Community colleges offer extensive opportunities for ERC educational activities. For example, community college students—and possibly faculty members—can be participants in short-courses/workshops/RET programs/design competitions offered by the ERC. Community-college faculty/instructor participants could then become on-site recruiters for opportunities in the ERC, and student participants in short-courses can interact with center-faculty to build relationships. Community colleges may also be fertile grounds for ERC graduate student presentations and teaching.

Community College Lessons Learned

Don't overlook campus outreach and recruiting professionals, who often have budgets and staff that have expertise in community college recruiting.

4.4.8 Veterans' Opportunities for Engagement in the ERCs

NSF recognizes that veterans represent a potential underutilized workforce for the U.S. science and engineering research and industry communities. Many veterans are transitioning from active military service to civilian careers and exploring education options through the post-9/11 GI Bill. At a time when the U.S. is challenged with a science, technology, engineering, and mathematics (STEM) workforce shortage, NSF is exploring alternate pathways of veterans' engagement into STEM fields.

To better engage veterans in engineering projects, NSF is soliciting requests from their active grantees for the Veterans Research Supplement (VRS)[3]. The proposed VRS will afford veteran students, veteran 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. See appendix section 4.4.7 for examples.

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

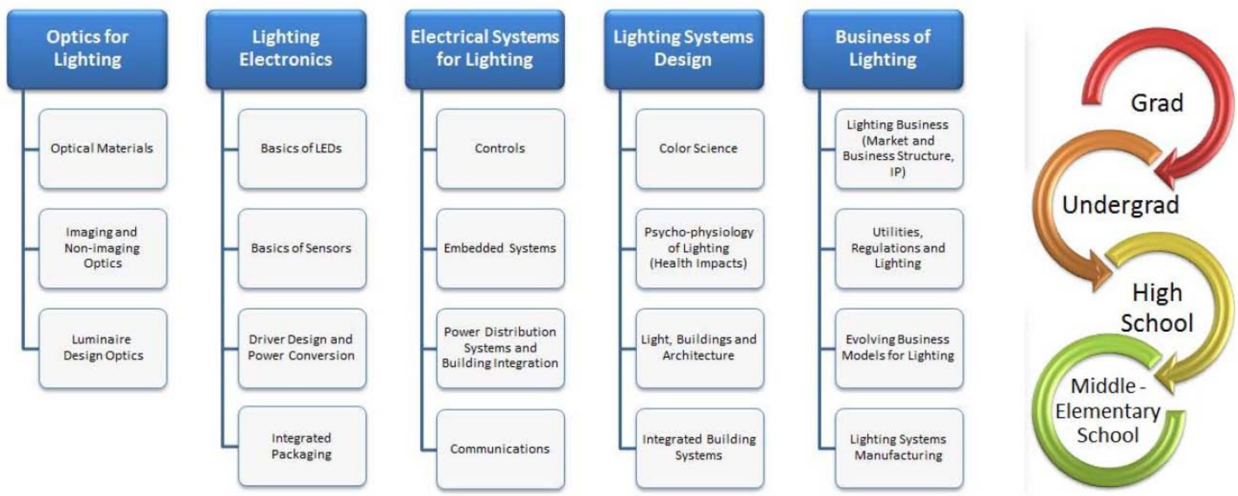
APPENDIX 4.4
UNDERGRADUATE EDUCATION EXAMPLES

4.4.1 Courses, Degree Programs

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

Type of Program: Strategy for university and precollege education

Program Synopsis: The Smart Lighting ERC developed the following matrix summarizing the desired background for graduates pursuing careers in smart lighting to guide the development of university and precollege programs. All Center constituencies assisted in this effort, 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.



Our hierarchical student-to-student mentoring structure helps facilitate the delivery of the education and outreach programs as we work to build the 21st Century Skillset in our graduates. All undergraduate 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 Engineering in general.

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

Dates of Operation/Timeframe: This program is ongoing.

Background: Smart Lighting is broadly multidisciplinary and involves background not generally found in traditional engineering and science disciplines. Examples include lighting and other types of building design, human physiology and health, economics and business, etc. Our industry partners were finding that students graduating from excellent universities were not conversant in the basics of lighting and those who knew something of lighting design (e.g., from schools of architecture) knew nothing of the science and engineering of solid state lighting. We defined a new discipline we call *Illumineering* to advance understanding of Smart Lighting by differentiating it from traditional Illumination engineering. The matrix we developed was designed for the development of modules for education and outreach, but its usefulness is not tied to any particular delivery approach.

Methodology: We began developing the *Illumineer Curriculum* by holding informal discussions with industry partners and then sharing the ideas identified with all of our constituencies. The first versions of the curriculum matrix were produced collaboratively by ERC Director Bob Karlicek and Education Director Ken Connor. Feedback on the matrix is now being obtained annually at our industry meeting, our faculty-staff-student planning retreat, and continuously from everyone using it to guide the development of education content. One of the key steps in any of our programs is to identify the aspects of the matrix that are included. Mentor training and mentoring activities are also formally included in all undergraduate programs.

Impact/benefits: One of the most difficult tasks for those working to develop new disciplines and industries is helping people understand what we are doing. The *Illumineer Curriculum* has been very helpful in telling our story. The student-to-student mentoring hierarchy helps students understand how to be better engineers in 21st Century society.

Evaluation/Assessment: Each program has a specific assessment process that uses 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.

Tips: 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 must be seen as essential, not an add-on, to achieve the best results.

4.4.1.2 ***Center*****:** Biotechnology Process Engineering Center (BPEC), a graduated ERC (1985–2005)
Lead Institution: Massachusetts Institute of Technology
Center Director: Dr. Linda G. Griffith, Department of Biological Engineering
Name of Program: Biological Engineering (BE) degree

Type of Program: New undergraduate degree program

Program Synopsis: In 2008, MIT created an entirely new course of study with their revolutionary Biological Engineering (BE) undergraduate degree program. This was the first new field of study to be established at MIT in 29 years.

Contact person/website: Dr. Linda Griffith (griff@mit.edu)

Dates of Operation/Timeframe: A regularly offered undergraduate degree.

Background: The program had its origins in the mid-1990s when the faculty at BPEC, now a graduated ERC, realized that there is a lot of fascinating—and necessary—research to do in the interface between biology and engineering. Their advocacy helped drive the establishment in 1998 of a new Biological Engineering Division at MIT, out of which the new degree program is a natural outgrowth.

Methodology: BPEC's Director, Linda Griffith, and former Director, Douglas Lauffenburger, were instrumental in shaping institutional consensus for the creation of the new degree program. The BE major started with just 20 undergrads and has grown in size over time as industry's demand for BE graduates has expanded.

Impact/benefits: There are endless future possibilities for this exciting, emerging academic field: One MIT researcher is studying how animals make their shells, and is using what she learns to develop advanced materials. Another investigator is building tiny chips with living liver cells to employ in drug testing. Still another uses DNA sequencing machines to create models of vast, shifting ocean microbe populations that play a crucial role in the life of the planet.

Evaluation/Assessment: Not available

Sustainability: The program is a formal part of MIT's undergraduate curriculum, under its own department.
Tips: Not available

Prof. Linda Griffith, then the Director of BPEC, was instrumental in establishment of the new undergraduate BE degree at MIT.

4.4.1.3 ***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: Undergraduate Neuroengineering Courses in Biomedical Engineering

Type of Program: Undergraduate courses and professional development events

Program Synopsis: The BMES ERC has developed and implemented four undergraduate courses over the past 10 years that are now required in the BME undergraduate program and integrated as an elective track (neuroengineering) in the undergraduate Biomedical Engineering (BME) curriculum. We have developed feeder courses including BME-201: "Biomedical Engineering Practice", a course aimed at giving undergraduate sophomores an appreciation of the complexity and multidisciplinary nature of the processes involved in the development of medical devices and the application of technology in health care delivery. This and the other three undergraduate courses (BME 414, 452, and 451) have been useful vehicles for giving our undergraduates early exposure to the research activities of the BMES ERC.

We have developed a series of annual major events aimed at providing our students at all levels the opportunity to network with local biomedical industry representatives. This has proven useful in helping some of these students find summer internships or permanent positions. These major events that were sponsored in part by the BMES ERC since the first year include:

- The Annual Corporate Dinner, organized by the Associated Students of Biomedical Engineering (ASBME), held in the academic spring semester each year. ASBME is an undergraduate student organization at USC. Over the last 3 years, it has grown to include Master's students in programs like MDDE.
- Since its inception, the Industry Internship Program has organized a BMES Industry Student Book, which is updated throughout the year and provided to our industry partners. The book consists of resumes and profiles of students who are interested in internships, employment or being mentored by industry. This has increased visibility of undergraduate students with industry members and helped to place students in internships. This book has also helped with placement for the Industry Mentorship Program.
- At the Annual Industry Advisory Board Meetings, students (including undergraduates) are the presenters for each of the Testbeds and Thrusts. This presentation opportunity has offered students time with our industry partners to share their research activities and share their career aspirations in a one-on-one setting.

At present, all ERC courses that are lecture-based have been video-archived, courtesy of the USC Distance Education Network, and the archived videos are available for access by students in ERC partner institutions through the BMES ERC website.

The BMES ERC has capitalized since its inception on the ongoing seminar series in Biomedical Engineering which was enhanced to include more talks on ERC-related topics. By its sixth year, the Center developed and implemented the Engineering Neuroscience and Health weekly seminar series. This course has become another successful mechanism through which students and faculty from engineering, medicine, neuroscience, and biokinesiology are brought together by research and clinical topics of common interest. The seminars are also video-archived and available for access by students and faculty from the ERC and its partner institutions. Additionally, the Keck School of Medicine at USC has introduced a seminar series on the newest findings in engineering research and medicine that is open to all students. All lectures are available via live feed and are archived and made accessible for future viewing.

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

Dates of Operation/Timeframe: We started these programs in years one through three of our ERC. They are all ongoing and fully developed.

Background: Comprehensive undergraduate programs with foci on BMES ERC research areas.

Methodology: We recruit for the programs via the universities, our website, our partner and affiliate universities, and those Minority-Serving Institutions (MSIs) with which we have relationships.

Impact/benefits: The objective is to expand student perspectives. The students gain much experience in engaging in interdisciplinary research, complete a full degree (s), and increase their engineering creativity and propensity for innovation (per our metrics of impacts). The majority of the students taking our undergraduate courses have gone on to graduate school. We track all students after graduation each year.

Evaluation/Assessment: Our courses all have course-specific content assignments and projects. Additionally, we have an annual questionnaire that includes interdisciplinary impact scales and innovation and creativity scales (ECPII). We have also developed course-specific concept inventories to measure knowledge in our undergraduate courses. We pair this quantitative data with an annual program focus group that we analyze thematically. We also track all students at all levels upon completion of the program into graduate schools and careers.

Sustainability: This program has been institutionalized at USC and is offered via the USC Distance Education Network to our partner universities.

Tip: Start designing courses and degree programs early and work at sustainability early on (at least by your third year).

4.4.2 Academic Year Research for Core ERC Undergraduates

4.4.2.1 ***Center*:** Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Lead Institution: North Carolina State University
Center Director: Dr. Alex Huang, Department of Electrical and Computer Engineering
Name of Program: Undergraduate Research Scholars Program (UGRS)

Type of Program: Year-long undergraduate research experience

Program Synopsis: The FREEDM Systems Center offers a year-long research opportunity for domestic undergraduates majoring in electrical and computer engineering, civil engineering, mechanical engineering, materials science engineering, computer science, and related fields at one of the Center's five partnering universities. This year-long research experience immerses undergraduate students in a more robust interaction with the Center's research teams and projects. In addition, students are required to attend bi-weekly program meetings, Center seminars and workshops, present at symposia, and submit a final project paper.

A $2000 stipend is paid for each semester, with a $500 travel award available to present research outside of the home university. Summer research is optional and not financially supported.

Contact person/website: Dr. Penny Jeffrey, Education Director at 919-513-3435, pmshumak@ncsu.edu, www.freedm.ncsu.edu

Dates of Operation/Timeframe: This program began with its first cohort of 15 in January 2012 and a second cohort of 12 in January 2013. Students participate in both spring and fall semesters; there are no paid summer opportunities. Students spend approximately 10-15 hours per week in the laboratory during the academic terms, and 2-3 hours monthly in cohort meetings with the Education Director, participating in both technical and professional development seminars and tours.

Background: FREEDM wanted to create a program with greater depth of both technical and non-technical components than those experienced in only one academic term undergraduate research program. Education research is discovering the benefits of a continuous, multiple term laboratory experience relative to awareness, understanding, and solidifying future education goals such as attending graduate school. Additionally, the Center has the resources to provide professional development opportunities that are crucial to a well-rounded engineering student entering into the workforce.

Methodology: The Education Director proposed the program and budget to the Center leadership. Once approved, the program was developed and advertised through Center faculty courses and website. Students apply to the program via formal application, letter of recommendation, letter of intent, and unofficial transcript.

Impact/benefits: This program enables faculty to get longer-term, more consistent interaction with undergraduate students, while students get to network and connect with Center industry members; spend more time learning technical aspects of research; interact with the Student Leadership Council (SLC); learn professional development skills such as resume preparation, oral and written communications (such as Perfect Pitch); and gain greater awareness of the holistic nature of research. Students meet as a Center cohort—getting to talk and discuss experiences across all partnering universities—as well as complete reflective writings to increase their awareness of their individual journey through the program.

Evaluation/Assessment: Pre- and post-program surveys measure constructs such as awareness and self-efficacy. The Center has been fortunate to work with Dr. Gigi Ragusa's research team to evaluate global preparedness, creativity, and innovation.

Sustainability: The Center is entering its sixth year and sustainability of this program will be further evaluated. Because of the direct connection with industry members and relatively low cost to run the program, we anticipate being able to have students sponsored by specific industry member companies.

Tips: A year-long undergraduate research program can present normal scheduling and year-long commitment challenges for undergraduate students. We have had two students out of 30 withdraw for non-program reasons. It is important to create opportunities for students to directly interact with Center graduate students (such as in Student Leadership Councils), partnering universities Undergraduate Research Scholars (via meetings), and industry members.

4.4.2.2 ***Center*****:** The Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems (Gordon-CenSSIS), a graduated ERC (2000–2010)
Lead Institution: Northeastern University
Center Director: Prof. Michael B. Silevitch, Dept of Electrical and Computer Engineering
Joint appointment to Department of Civil and Environmental Engineering
Name of Program: NSF's Louis Stokes Alliances for Minority Participation (LSAMP) program

Type of Program: Year-round Research Experiences for ERC Undergraduates

Program Synopsis: This program was intended to provide funding for underrepresented engineering students to engage in research while in school and during the summer. Beyond the usual 10-week summer research experience, it provided support for selected undergraduates from underrepresented minority groups throughout the school year.

Contact person/website: Kristin L. Hicks, Director of Operations, Gordon-CenSSIS at 617-373-5384 or k.hicks@neu.edu or Prof. David Kaeli at 617-373-5413 or d.kaeli@neu.edu.

Dates of Operation/Timeframe: At the time, this program was offered year-round and students could apply for Northeastern LSAMP (NELSMP) funding for part-time work during a semester.

Background: The NELSAMP funding was useful to supplement the NSF REU funding that Gordon-CenSSIS received, in order to increase the number of students who could participate in Gordon-CenSSIS research. Some students came to CenSSIS through the NELSAMP program. In addition, two Spelman College female students were supported through the NSF REU funds.

Methodology: The NELSAMP Program had an application process through which undergraduate students had to apply and specify who they would work with, what type of research they would be doing, and how many hours they would work per week. If accepted, the student received hourly pay for the hours worked.

Impact/benefits: This program was important because it encouraged and supported the involvement of underrepresented students in interesting research. Through a series of programs like this, Gordon-CenSSIS tried to involve as many interested students as possible. For example, Nicolas Dedual was a participant in the LSAMP program. He worked with professors David Kaeli and Dr. George Chen to develop a four-dimensional visualization toolset and completed his BS in Computer Engineering in 2006. He is currently pursuing a PhD in Computer Engineering at Columbia University. He is the founder and owner of Dedual Enterprises, a provider of technological solutions with an emphasis on mobile device development, augmented reality applications, and technical training services. The two Spellman College students graduated, and one went on to obtain an MBA. Another NELSAMP student from that group, Burak Erem, completed his Electrical Engineering degree at NU in 2006 and received his PhD there in 2013. He is currently at Boston Children's Hospital working as a Postdoctoral Fellow.

Evaluation/Assessment: It is not known what assessment tools were used by the NELSAMP group at that time,

Sustainability: The program organizers have continued to use the NELSAMP program at NU to connect interested students with potential research projects. They also run a similar program, known as the Gordon-CenSSIS Scholars Program, which gets students involved in research in their freshman year by providing a book voucher in exchange for their successful participation in research.

Tips: The key to sustaining interest in research participation is to make sure that a student has resources to refer to for questions, assignments, and feedback. There need to be a few people (faculty advisor, graduate student mentor, fellow undergraduates) who will check in with the student regularly to make sure that they know what they should be doing.

Nicolas Dedual, former NELSAMP student at CenSSIS

4.4.2.3 ***Center***: ERC for Quality of Life (QoLT)
Lead Institution: Carnegie Mellon University
Center Director: Dr. Dan Siewiorek; home dept.: HCII: Human Computer Interaction Institute
Name of Program: QoLT Undergraduate Program

Type of Program: Academic year Research Experiences for Undergraduates

Program Synopsis: We facilitate academic year "REU-like" programs for students at our core ERC institutions.

Contact person/website: Mary Goldberg (mrh35@pitt.edu), www.qolt.pitt.edu

Dates of Operation/Timeframe: This program runs in the fall and spring semesters.

Background: The QoLT Center Student Leadership Council (SLC) students requested the opportunity to mentor students over the academic year. As a result, the SLC students developed their own "REU-like" program that takes place in both the fall and spring terms, which is funded by the Center.

Methodology: The SLC (typically the co-chair and education chair) manages recruitment of projects and students. They then match the students to projects and coordinate supplemental activities throughout the term to engage participants. Students are paid out of QoLT Center funds, not the REU program ERC core funds nor REU Site grant funds.

Impact/benefits: QoLT has a societal goal that is explicitly woven into the concept of broad impact: how can technology be used to effect positive social change in the lives of the elderly and in the lives of persons with disabilities? Students conduct leading research that has direct effects on peoples' lives. The value of the sense of worth that a young engineer-to-be obtains from such an experience early in his or her training cannot be overstated. Coming from diverse backgrounds, students integrate their research experiences with planned curriculum devoted to research, design, and integration methodology.

Evaluation/Assessment: Formative and summative assessments are conducted at several phases of the program, including recruitment, internship training, and post-internship follow-up. An SLC rep meets with the students regularly to assure that their research interests and needs are being met. To assess the experience from the perspective of faculty advisors and graduate student mentors, a separate survey is administered at the end of the program. All surveys are web-based and allow for direct data entry, ease of tracking program outcomes, and electronic storing of the data. The data captured include if, and where, the student pursued graduate studies and where they are employed, if applicable. Before the students leave the program, they are asked to provide contact information so they can be reached in the future. Every year an email with the link to the follow-up form is sent to each person with a read - receipt flag to notify us if/when they receive it. Students who do not respond are called and interviewed over the phone.

Sustainability: Thus far, the program is only funded by the ERC.

Tip: Additional coordination by the E&O director (or staff) is helpful to organize logistics and evaluation efforts.

4.4.2.4 ***Center***: ERC for Computer-Integrated Surgical Systems and Technology (CISST), a graduated ERC (1998–2008)
Lead Institution: The Johns Hopkins University
Center Director: Dr. Russell H. Taylor, Department of Computer Science
Name of Program: A design and development project course

Type of Program: Undergraduate research leading to prototype product

Program Synopsis: CenSSIS Professor Ralph Etienne-Cummings' project course in electronics design and product development required students to conceptualize a needed product, conduct research to see whether the product exists, analyze what is available in the marketplace, and then develop their own product to address the gaps. Typically, the devices developed are biomedically oriented. In one example, Johns Hopkins University undergraduate students Elen Tsai and Helen Schwerdt, then working in a laboratory of the CISST, developed a glove that could potentially give a blind person the ability to sense color. Ms. Tsai and Ms. Schwerdt developed a final prototype, which was then evaluated through a rigorous experimental protocol using human subjects.

Contact person/website: Prof. Ralph Etienne-Cummings, retienne@jhu.edu

Dates of Operation/Timeframe: 2007-present

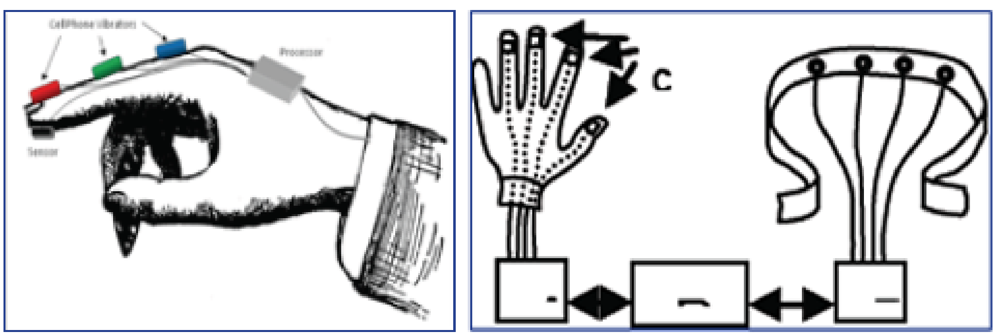
Background: Providing undergraduates with an environment and an opportunity to carry out original research leading to a prototype product with strong potential utility is one of the hallmarks of an ERC.

Impact/benefits: The benefit of this project course is primarily educational. In the example described, the prototype did not go to market. The students published papers in international conference, received local publicity, and even migrated from an undergraduate project to a masters project. A few other students continued worked on the project. Most of those students are now pursuing PhDs, while one is working for a biomedical device company.

Evaluation/Assessment: Not available

Sustainability: Not available

Tips: Not available



Prototypes of the ColorGlove with 4 tactile feedback "tactors." The first three fingers are instrumented with color sensors, also shown enlarged to the right. The color information from the sensors is communicated by the combination of position, amplitude, and frequency of vibration.

4.4.3 Summary Research Experiences for Undergraduates (REU)

4.4.3.1 ***Center***: Smart Lighting ERC
Lead Institution: Rensselaer Polytechnic Institute
Center Director: Prof. Robert F. Karlicek, Jr., Dept. Electrical, Computer, and Systems Engineering
Name of Program: Smart Lighting Research Experiences for Undergraduates (REU)

Type of Program: REU [funded through the ERC's core budget]

Program Synopsis: The Synthetic Lighting ERC supports a 10-week summer research program for visiting undergraduate researchers each year. Each participant becomes a member of one of the research groups in the Center and is assigned a graduate student mentor. Research projects are assigned by the research faculty advisor. In addition to research group meetings, participants are asked to attend weekly REU seminars, field trips, and lab tours. This provides students with opportunities to interact with participants in other Rensselaer campus REU programs. The program culminates with the REU Symposium at which each participant gives a poster presentation demonstrating their accomplishments and an overview of the summer research experience. Participants are housed in suite settings to encourage an interdisciplinary community, with full use of institute and departmental facilities, including libraries, computer facilities, shops, recreational, and sports facilities.

Contact person/website: http://smartlighting.rpi.edu/education/REU.shtml

Dates of Operation/Timeframe: While the program for the undergrad participants runs full time for 10 weeks from the last week of May to the first week of August, ERC personnel are involved year round, including recruitment and publicity.

Background: The overall student experience we strive for in Smart Lighting combines education, mentoring and outreach with laboratory research. Thus, the REU program was designed in provide a diversity of activities for all participants, including undergraduate students, graduate students, staff, and faculty. In addition, we have built on a long-term relationship with a local college that focuses on teacher education (The College of St Rose) to involve their students in the REU experience with the goal of expanding their STEM horizons and providing a more engaging experience for the engineering and science majors.

Methodology: The REU and Research Experiences for Teachers (RET) (see 4.3 Precollege section) programs are planned and run together. The yearly sequence of events is outlined below.

<u>September</u>
- E&O leadership review previous year's activities and modify plans for the coming year.

<u>October</u>
- Requests for project descriptions to ERC faculty. Information requested:
    - One paragraph project description *including specific goals*
    - Relevant student/teacher background
    - SACNAS and SWE Recruiting

<u>November</u>
- AISES Recruiting
- Schedule and budget for REU and RET programs in coming year defined
- General program information updated on ERC website
- Project Descriptions Due Mid-Month
- Requests for project resources to ERC faculty. Information requested:
    - Relation to ERC and its mission (thrusts, testbeds, industry partners, education and outreach partners, etc.)
    - Facilities, materials and supplies (project budget)
    - Possible graduate student mentors
    - Information on Role of Mentors sent to ERC faculty and students
    - Online Application Materials Posted on ERC Website

<u>December</u>
- Applications accepted until first week of March
- REU request to partner schools for candidates with project plan summary, include request for information on any local REU and RET programs that will be asked to support Smart Lighting projects.

January

- Project Resource Specification Due
- RET request to regional K-12 schools (for all partners with supporting programs) and publicity posted on campus websites

March

- First week deadline for completed REU applications
- Mid-month deadline for selection of candidates by meeting of E&O leadership and thrust leaders. Discussion will also include recommendations for technical seminars and activities, training for mentors, final summer schedule, etc.
- Offer letters set out
- Summer Schedule finalized including plans for technical and social collaboration with other programs on each participating campus (e.g., Biomedical Engineering REU site at RPI, summer research program at Rose-Hulman, etc.)
- NSBE Recruiting (for following year)
- ECEDHA Diversity Meeting (HBCU and Hispanic serving ECE department heads)

April

- Processing of participants after receipt of signed offer letter
- End of month deadline for receipt of signed offer letter
- Mentor training workshop

May

- Background materials provided to participants
- Dialog with participants begins online through both social networking and more secure information sharing medium.

May – August Summer REU Program

- Week 1: Orientation and Smart Lighting Overview with topics addressed including Smart Lighting fundamentals, responsible conduct of research, ethics, leadership, communication (writing and speaking), etc. Seminar series begins addressing both technical and professional development topics. There is also a welcome barbeque. Students present on their research topics at the end of week 1.
- Weeks 2 – 10 Research projects with related educational development. Key activities:
- Week 2 – Students participate in ERC site visit
- Weeks 2 to 8 – technical seminars and student development (e.g., applying to grad school) workshops
- End of weeks 3, 5, 7 – mentors submit progress memo and students lead tours of their labs for all REU participants.
- Weeks 5 and 7 – Technical research participants mentor high school students and teachers during one day of week-long summer programs. Pre-service teachers involved in educational research help organize and lead high school programs.
- End of week 6 – Participants do 5 minute progress report and submit draft of final report for feedback from mentors and E&O leadership (video conference). Mid-program assessment.
- End of week 10 – Program poster symposium with student presentations and final report submitted. Top presentations and reports selected for permanent posting on ERC website. End of program assessment.

Post Program

- Subsidized student participation at conferences where summer work is presented
- Continued interaction of participants and mentors at all levels
- Participation in education, outreach and recruiting activities by participants and mentors.
- Follow up assessment

- Participant tracking

Impact/benefits: The traditional goal of the REU program is to help identify and recruit promising STEM undergraduates to graduate studies, especially in Smart Lighting. Of equal importance in this program are to (a) help engineers and scientists of the 21st Century engage in the community as a whole rather than just with their research lab colleagues, and (b) help future teachers learn to better integrate relevant content from the research lab in their classrooms and engage in educational research. The most exciting results of this program become evident each year during the first high school program where, with the help of their faculty mentors and especially from the engineering and science REU students, pre-service teachers have their "*eureka!" moment* and realize they can do what engineers and scientists do and will be able to share their knowledge with their future students. This almost always manifests itself when the teachers first successfully help a high school student debug a circuit.

Evaluation/Assessment: Student and mentor surveys, interviews and continued interaction through social networking (Facebook and LinkedIn).

4.4.3.2 ***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: Lab Fundamentals Bootcamp

Type of Program: Undergraduate non-credit course for REU students

***Program Synopsis**:* SynBERC has launched a five-day hands-on workshop that provides a comprehensive primer in microbiology and molecular biology, research methods, safety and human practices, experimental design, and demonstrations of basic techniques likely to be encountered in a molecular biology lab. The course is intended for undergraduates who have no prior experience working in a research lab.

Contact person/website: Kate Spohr (kspohr@berkeley.edu), http://qb3.berkeley.edu/qb3/bootcamp.cfm

Dates of Operation/Timeframe: The program was initiated in 2010. The workshop is offered three times in spring and early summer, with up to 20 students per session. It meets Mon-Friday, 9 am to 5 pm.

Background: REU students from primarily undergraduate institutions often have significant gaps in their academic preparation and research skills. They also lack basic knowledge of how a lab works and what the expectations and norms are within a research group. Thus, at the beginning of their REU, they require more intensive training and take longer to adjust to the lab environment. SynBERC created the Lab Fundamentals Bootcamp to address this gap.

Methodology: In spring 2010, two SynBERC graduate students with strong teaching/mentoring backgrounds were hired to develop the Bootcamp curriculum. They used training materials developed for iGEM and lab-based Synthetic Biology courses offered at Berkeley and MIT. The curriculum development process was overseen by two SynBERC faculty members, and the course was piloted the following summer with two REU students from SynBERC's outreach institution. Major expenditures (in time and money) for the program were incurred in the first two years, as the program was developed, piloted and refined. Once the curriculum was created, we have found it quite easy to continue the program, and have even expanded from one to three Bootcamps to meet campus demand from outside departments and programs. Each new group of instructors is trained by the previous year's instructors.

The curriculum is continuously revised and refined based on student/instructor feedback.

Impact/benefits: Mentors report that students who have undergone Bootcamp training require less intensive training in the first weeks of the REU, are able to achieve independence in the lab more quickly, and are more productive overall. Students who participate in the Bootcamp self-report greater confidence and higher satisfaction with the REU experience. The Lab Bootcamp also offers valuable teaching experience to SynBERC graduate students.

Evaluation/Assessment: Program assessments are conducted via questionnaires and interviews. A post-program instructor focus group is held after each Bootcamp.

Sustainability: SynBERC's umbrella organization, QB3, is committed to sustaining the program once SynBERC graduates from the ERC program. Tuition is charged for students who are funded through grants. These fees defray 80% of program costs.

Tips: Bootcamps are a cost effective way to provide high-quality training to undergraduates and significantly reduce the time required of mentors in REU programs. By starting the summer off with a group of peers who are new to research, REU students quickly become part of a cohort that provides moral and social support for them throughout the summer.

Sustainability: Other sources of funding include other REU and undergraduate research programs (e.g., REU sites and supplements), inclusion of research students from other programs, and industry support.

Tips: In the first year of this program, we did not begin the planning and general preparation process early enough. This is a year-long activity for the leaders. We also did not insist on air conditioned dorms and housing the students as close together as possible. Good housing conditions conducive to student interaction helps build the sense of community necessary for the best possible learning experience. In programs that are constructed well, students will learn more from one another than from us. Leveraging other undergraduate research programs, especially REU sites, to involve more students and to reach critical mass for professional development and social activities can be complicated, but it is definitely worth it. The leadership from each program has great ideas and everyone benefits by combining them. We focus on recruitment from our outreach partners—including two HBCUs and a few other schools—by identifying key people to help identify the best possible student applicants. We also help place these students in other programs if we have no space for them in ours.

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

Type of Program: REU planning strategy

Program Synopsis: Groups of REU interns from different departments on campus come together to participate in joint functions during the summer, such as seminars and social events.

Contact person/website: Jodie R Hanzlik, Dean, Graduate School (jodie.hanzlik@colostate.edu)

Dates of Operation/Timeframe: The program begins with a planning meeting early in the Spring semester so that the coordinator can get an idea of the number of students and compile a calendar of proposed events. The program runs through the summer.

Background: Most REU programs have similar goals for providing both learning and social opportunities to participants. To make the execution of these common goals more efficient, the research groups that hosted REU programs formed a cooperative supported by administrative help and funds from the Graduate School.

Methodology: This type of program requires communication and coordination between the different groups that sponsor REU programs.

Impact/benefits: The REU interns benefit from this program since they are able to participate in enrichment activities that have been designed and modified for a larger audience than they would have experienced through individual departments. In addition, because they participate in these activities with a larger number of students, they benefit from increased social interaction. The majority of students who participate in REU programs are from different universities, so the cooperative provides a venue for students to form valuable social connections during the summer. Finally, the presence of a CSU-endorsed group on campus instills confidence in students who might apply for graduate school and shows funding agencies that CSU is concerned and cares about students.

Evaluation/Assessment: We evaluate the program through Informal discussion with cooperative members.

Sustainability: The program does not necessarily require funding. However, a minimum amount of support from the University (e.g., the Graduate School) is extremely beneficial.

Tip: Document the group activities and make sure that the University's administration is aware of the cooperative.

4.4.3.4 ***Center:*** ERC for Quantum Energy and Sustainable Solar Technologies (QESST)
Lead Institution: Arizona State University
Center Director: Dr. Christiana Honsberg, Department of Electrical Engineering
Name of Program: Solar Energy Research Experiences for Undergraduates (REU)

Type of Program: REU [funded through various sources: the ERC's core budget, university REU awards, and a veterans' research supplement]

Program Synopsis: QESST recruits undergraduate students from around the nation to spend five weeks learning about photovoltaics through the student pilot line at Arizona State University (ASU). Through the mentorship of QESST faculty and QESST scholars, participants in the program have the opportunity to conduct authentic research on a full scale solar manufacturing line.

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

Dates of Operation/Timeframe: QESST began this program in June 2012 as a five-week program in which students participated Monday through Friday from 9:00 a.m. to 5:00 p.m.

Background: The rapid growth of the photovoltaic industry and the need for it to contribute substantially to energy security requires that education explicitly support the development of the necessary skills and mind-sets for innovation and broader communication among the next generation of photovoltaic scientists/engineers. Scaling up new PV devices into large scale manufacturing require that a number of technology and policy issues be addressed, including: developing diagnostic tools and predictive models for production lines; creating ways to assess the reliability of PV technology and analyze the failure and degradation of the mechanisms in PV modules; inventing manufacturing approaches, processes, and equipment suitable for rapid scale-up; and preparing policies to promote rapid increases in production capacity. The student- led pilot line at ASU provides student with the unique opportunity to examine and participate in research on each of these issues.

Methodology: The goal of the REU is to use existing laboratory resources to build a comprehensive introduction to silicon solar cell fabrication. Achieving this goal takes a strong team of mentors to assist with REU participants. Therefore, QESST Research Assistants are identified early on based on their leadership skills and knowledge of various lab processes. Once identified, these scholars are prepared to be mentors by QESST faculty and become part of the REU planning team.

Recruiting REU participants is conducted via three approaches: advertising on the QESST website (http://qesst.asu.edu/education-and-outreach/reu), spreading the word among QESST partner and affiliated universities, and connecting with institutions (e.g., community colleges) associated with QESST institutions through various partnerships and outreach initiatives.

Participants in the program are provided with travel funding, lodging, and a stipend. The program begins with safety training, which is required for full participation in the lab. After safety training, participants are guided step by step through the silicon solar cell fabrication process for two weeks. They are then divided into teams to conduct individual research projects. Through the final three weeks of the program, QESST scholars serve as mentors to REU participants as they conduct their research. Throughout the program, the REU students also participate in lunchtime lectures focused on topics such as graduate school, nanomanufacturing, semiconductor fundamentals, and sustainability. These lectures are shared through video conferencing with QESST partner institutions, allowing the REU students to connect with other QESST faculty, scholars, and REU participants across the ERC. At the conclusion of the program, the students present their research in a poster session, where they are joined by young scholars, RET teachers, and other REU students from across QESST.

Impact/benefits: The Solar Energy REU combines the multidisciplinary nature of the pilot line with the diverse backgrounds of the REU participants to build a solid foundation of transdisciplinary knowledge while helping to build a deep social and global awareness. By engaging in research that is often outside of their current field of study, participants are encouraged to become intellectual risk takers. Ultimately this program fosters innovation and creativity and produces students who are prepared to expand the field of photovoltaics both within engineering and the broader community.

Evaluation/Assessment: Formative evaluation examined project progress in meeting objectives and completing planned activities in relation to established time lines. Completion of activities associated with the pilot line and ancillary activities are documented with attendance logs, bibliography of reading materials, research protocols, production records, student research reports/manuscripts, and student posters. These data are collected and archived by Project Principal Investigators (PIs) and Research Assistants (RAs). PIs and senior faculty review documentation weekly to assure that activities are completed on schedule. As part of formative evaluation, REU students are asked to complete a post-survey about their experience, which rated the specific course curricula and activities based on utility and interest, and encouraged suggestions for summer research experience improvements. Formative data is reviewed annually by senior faculty to inform changes and revisions to the summer experience and activities. In addition, recruitment records are compared to recruitment goals for targeted student groups.

Sustainability: To make this program sustainable, QESST has sought out additional sources of funding, including site awards and veterans' supplements. This past year, three of QESST's five REU participants were funded through a veterans' supplement. QESST has also sought funding from its home university. Last year, ASU's Ira A. Fulton Schools of Engineering funded ten students to take part in the REU.

Tips: Staffing the REU can be difficult. It takes a big commitment on the part of faculty and student mentors to successfully run the program and the summer schedule often is in conflict with vacation schedules. It takes a lot of planning to make sure that the REU has the coverage that it needs to be successful, while at the same time allowing the mentors to take their vacation days.

Note that, due to the nature of the chemicals used in our lab, our facilities are not located on campus. For centers with off campus facilities this can pose a challenge if there is no reliable public transportation from the dorm housing to the lab. At ASU we have had to rely on either participants with cars or student mentors to carpool with our guests from out of town.

4.4.3.5 ***Center*:** ERC 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 Undergraduates (REU)

Type of Program: REU [funded through the CSNE's core budget]

Program Synopsis: CSNE runs a 10 week Research Experiences for Undergraduates (REU) program during the summer, hosting approximately 15 REU students in UW Center-affiliated research laboratories every year. All participating students are paid a stipend of $5,000; out of town students are also provided with housing in University of Washington (UW) facilities and given a $750 travel allowance. In addition, the 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. Five REU positions are reserved for students from the CSNE domestic partner institutions including Massachusetts Institute of Technology, San Diego State University, Southwestern College, Morehouse College, and Spelman College. Five of the remaining students come from the UW and the other five come from other institutions around the country. In addition to being integrated into laboratory research, the REU 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 cover topics such as reading and writing scientific journal papers, making scientific poster presentations, preparing and delivering scientific talks, and communication of scientific concepts to lay audiences. Students also attend a series of special seminars on topics including the responsible conduct of research, industry and intellectual property, preparing for and applying to graduate school, and neuroethics. At the end of the 10 week program, CSNE REU students join approximately 100 other undergraduate students who work on other UW summer research projects to present posters about their research at a University-sponsored research symposium. REU students also make 15 minute oral slide presentations to members of the CSNE community. Some REU 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/research-experienceundergraduates-reu

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

Background: The CSNE Executive Director was previously the education director for UWEB (a graduated ERC) and the CSNE REU program was modeled after that Center's program.

Methodology: The REU program is, at this point, funded entirely by the CSNE core budget. The REU 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 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. Airfare and housing for out-of-town participants is arranged directly by CSNE administrative staff. Participants are paid every two weeks.

Impact/benefits: The REU program allows students who would otherwise not have the opportunity to be involved in cutting edge research to see how academic labs function and to get a feel for what graduate school would be like. The CSNE is focused on increasing the diversity of the next generation of neural engineers and the REU program is one way help underrepresented students get experience in this field.

Evaluation/Assessment: The CSNE contracts with external education evaluators at the Center for Research and Learning. These evaluators have designed a post-program survey which they administer to the students. The survey measures the program's impact on the CSNE target skill sets and attempts to capture the perceived benefit to participants and the impact of the program on their future educational and career plans. According to this survey, 93.3% of the 2012 students strongly agreed that participating in the program was a valuable experience and 100% of the students said they would recommend the CSNE REU to others. In follow-up interviews conducted five months after the end of the program, 100% of the students surveyed indicated that they: a) planned on majoring in a STEM field; b) were more confident with their research and lab skills since their summer research experience; and c) were satisfied with their experience.

Sustainability: We are currently applying for an NSF site grant for the REU program.

Tips: It is important to define the expectations for both the students and the mentors in advance of the program to avoid misunderstandings.

4.4.3.6 ***Center*****:** ERC for Ultra-wide Area Resilient Electric 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: Research Experiences for Undergraduates (REU)

Type of Program: REU [funded through the ERC's core budget]

Program Synopsis: CURENT's REU program operates during the summer and semester terms. CURENT recruits undergraduate sophomores, juniors, and seniors from prominent engineering universities across the nation to participate in research relating to power systems, power electronics, cyber security, wireless communication, and renewable energy. Students are exposed to training in fundamental engineering knowledge and computer programming (e.g., Matlab, Labview, or C), as well as professional development. REU students are expected to present an oral presentation, a technical poster, and a technical paper. During the summer term, students are required to present at the STEM REU Symposium at the University of Tennessee. Among the research projects to date are smart home design and monitoring, hardware testbed emulation, optimizing demand side management of electric markets, power grid frequency visualization and monitoring, synchronous time data collection of frequency data, and methods of impedance measurements.

Contact person/website: *Chien-fei Chen; education and diversity co-director (*cchen26@utk.edu), http://curent.utk.edu/education/university-education/reu/

Dates of Operation/Timeframe: 8 week summer program (9-5pm); or 10-20 hours during the semester

Background: The REU program provides undergraduates the experience of being a researcher within a laboratory during the summer or academic term. A full time experience during the summer term allows students to develop an idea of how being a graduate student is different than being an undergraduate student. The program encourages students to continue their education in graduate school.

Methodology: This program includes seminars, research meetings, progress reports and mentor feedback from the faculty, working alongside graduate students, and non-technical professional skill training. Throughout the summer term, for example, REU students attend research meetings, seminars, and field trips. By the end of the program the students submit an oral presentation, technical poster, and technical paper. While mentored by faculty and graduate students, REU students expand upon research projects being investigated by the faculty. Typically, a group of 10 undergraduates are selected to participate. In early spring, advertisements of the program are sent out to electrical engineering departments across the country. The students are asked to fill out several surveys regarding their background, provide an academic transcript, and write an essay describing their interest in research. After evaluating candidates based on grade point average, academic progress, and reasons for applying, selected students are initially paired in an area that matches their interests. Summer participants are provided with a stipend, university housing, and travel reimbursement as needed. Academic-year REU students work about 10-20 hours weekly directly with CURENT faculty.

Impact/benefits: After participating in this program, REU students have a greater understanding of the expectations of graduate level research and understanding of the connection between research and engineering in industry. The program promotes the student's interest in research since they are exposed to numerous significant research projects that encourage the continuation of study in graduate school. In addition, REU participants are exposed to professional and programming related trainings. Graduate student mentors have opportunities to communicate and train undergraduate students.

Evaluation/Assessment: Bimonthly interviews are performed with each student to monitor their progress and interest in the program by the education team. Faculty members, the education coordinator, and the director interview the students periodically to determine their progress and need for resources. In addition, pre-, post-, and follow-up surveys are used to determine the students' overall perspective about engineering. Lastly, a program evaluation is required to evaluate the program structure and determine areas for improvement.

Sustainability: Three possible ways to sustain this program include: a) leveraging with university organizations, national labs, or industry partners; b) seeking grant opportunities from NSF (e.g., REU-site proposal) or other agencies; and c) seeking financial support from faculty who have other NSF grants.

Tips:

- Explaining the value of mentoring REU students to graduate students and faculty members is the key to success.
- Accessibility to propriety-licensed software can be difficult to obtain for visiting undergraduates. Sometimes a stand-alone license is needed or alternative software must be selected.
- Not only are periodic undergraduate interviews helpful, but so are graduate student interviews. Much of the REU experience is dependent upon interaction with the graduate mentors. A mentorship training session is highly recommended to assure graduate students know how to interact with and mentor undergraduate students.

- Expand the program by including more faculty members from departments (e.g., electrical engineering and computer science) beyond the affiliated faculty at the Center. Recruitment should start as early as October or November by sending emails, flyers, and letters to women and minority organizations at major universities and community colleges nationwide. A presentation about the program in person is another effective way to recruit students.

A happy group of students and faculty were photographed during CURENT's inaugural Research Experiences for Undergraduates summer program in 2012.

4.4.3.7 ***Center*****:** Future Renewable Electric Energy Delivery and Management Systems Center (FREEDM)
Lead Institution: Carolina State University
Center Director: Dr. Alex Huang, Department of Electrical and Computer Engineering
Name of Program: FREEDM Summer REU program

Type of Program: REU [funded through an REU Site award in 2010, 2011, and 2012]

Program Synopsis: This is the standard 10-week NSF summer REU program that provides a research opportunity to domestic undergraduate students from universities outside of the Center who are majoring in electrical and computer engineering, civil engineering, mechanical engineering, materials science engineering, computer science, and related fields. The undergraduate students spend 10 weeks during the summer working directly in the research laboratories of Center faculty for up to 40 hours per week, while being mentored by Center graduate students and possibly Center undergraduate student researchers. The summer REU students also engage with the precollege Young Scholars (YS) and RET programs through technical seminars, tours, and meetings. The Center theme of "Each One Mentors One" embraces the importance of having peer-to-peer mentorships involving participants of the precollege programs, other undergraduate researchers, as well as graduate student researchers. At the culmination of the program, students present their research and professional experiences to the entire Center faculty, staff, and students. Most students also present a research poster at their respective host universities.

A $4,000 stipend is paid for the ten-week summer research experience. On-campus dormitory-style housing is provided as well as $500 for travel reimbursement for those students arriving outside of a 50 mile radius of the host university.

Contact person/website: Dr. Penny Jeffrey, Director of Education (pmshumak@ncsu.edu), www.freedm.ncsu.edu

Dates of Operation/Timeframe: The REU program recruited its first cohort for the summer of 2009. The program takes place at all partnering universities for 10 weeks during the summer. Students spend up to 40 hours per week in the laboratory. Additionally, REUs meet as a Center cohort with the YS/RETs for technical seminars given by faculty and other guest lecturers. The REUs also meet weekly as a cohort to learn other professional development skills such as the Perfect Pitch, resume development, ethics, diversity, and research poster development.

Methodology: Students are recruited through email listservs as well as the joint-ERC recruitment booth at SACNAS/AISES, HBCs, and other universities, colleges, and community colleges that have a population of under-represented minority groups interested in engineering. Students apply to the program via formal application, letter of recommendation, letter of intent, and unofficial transcript.

Impact/benefits: The program introduces undergraduate students to the holistic nature of engineering research and in some cases solidifies interest in attending graduate school.

Evaluation/Assessment: Pre- and post-program online surveys are conducted to evaluate constructs such as self-awareness, understanding, creativity, and innovation. The Center has been fortunate to work with Dr. Gigi Ragusa's research team to evaluate the creativity and innovation survey data.

Sustainability: We are currently in our sixth year and are evaluating programs for sustainability. We are fortunate to be able to collaborate with other REU programs to share sustainability approaches.

Tips: It is important to recruit widely through universities, colleges, community colleges, student organizations, to get a dynamic set of applicants. Administrative support to assist with establishing student stipends and housing is imperative. Most universities require visiting summer participants to have liability insurance. Collaborate with other existing REU programs at your university.

4.4.4 Summer Design Project

4.4.4.1 ***Center***: ERC for Quality of Life (QoLT)
Lead Institution: Carnegie Mellon University
Center Director: Dr. Dan Siewiorek; home dept.: HCII: Human Computer Interaction Institute
Name of Program: Technology Innovations for People with Disabilities (TIPeD) Program

Type of Program: Summer product development internship program

Program Synopsis: Business and engineering students (from the REU program) work together on teams to develop products and business plans.

Contact person/website: Mary Goldberg (mrh35@pitt.edu), www.qolt.pitt.edu

Dates of Operation/Timeframe: This program runs from the last week of May to the beginning of August.

Background: Assistive Technologies (ATs) can be the single most important factor in determining whether people with disabilities (PWD) can participate fully in society. Unfortunately, the AT market itself does not necessarily drive innovation like it does in other product domains. Academic institutions are a great resource for innovation and faculty and students are deep wells of creativity, in part because they are unencumbered by market circumstances and regulations which can stifle novel solutions. While the academic environment fosters this creativity, many of these innovations fail to transfer to the commercial market. A promising approach is to leverage the internal programs at the university to support technology commercialization. For example, pairing technology innovators with students and faculty from business and law schools provides the appropriate mix of skills to innovate and bring the technology closer to marketability. This approach helps educate the innovators early on about the importance of the market forces, and also provides actual technology for the business and law students to work with.

Methodology: Teams (consisting of students from the engineering, business and clinical disciplines and either a faculty or graduate student mentor) spend ten weeks working on a technology innovation project in the area of the mentor's interest. During that time, they are required to make substantial progress on the technology design and to generate a business and commercialization plan in the form of a Small Business Innovation Research (SBIR) grant proposal for a start-up business to commercialize the product. Through involvement in these projects and lectures, students learn the fundamentals of entrepreneurship, including design processes, intellectual property considerations, and business plans.

Impact/benefits: Students are able to integrate their product development experiences with a planned curriculum devoted to design, intellectual property, and technology transfer strategies, enabling them to develop products that have direct effects on peoples' lives. The value gained from the sense of worth a young engineer-to-be obtains from such an experience early in his or her training cannot be overstated.

4.4.5 Community College REU

4.4.5.1 ***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: Transfer-to-Excellence REU Program (TTE REU)

Type of Program: REU for California community college students with strong advising component [an REU Site award to the ERC in 2012 and 2013]

Program Synopsis: TTE REU is a partnership of three NSF-funded Centers at UC-Berkeley—SynBERC, the Center for Energy Efficient Electronics Science (E3S), and the Center of Integrated Nanomechanical Systems (COINS)—whose aim is to advance California community college science and engineering. Though each Center has a different disciplinary focus (nanotech, biotech, and electrical engineering), the REU is integrated into an overall research effort aimed at developing innovative solutions to energy problems. The site supports 15 community college students from the California Community College System (CCCS) each year. Collaboration with the University of California-Berkeley (UC-Berkeley) Transfer Alliance Project (TAP) provides individualized academic and transfer advising and enrichment programs that prepare students to be competitive applicants to four-year colleges. The transfer advising begins in the summer and continues for one academic year after completion of the REU.

Contact person/website: Sharnnia Artis (sartis5@berkeley.edu) or Kate Spohr (kspohr@berkeley.edu), http://www.e3s-center.org/education/edu-tte-reu-appl2.htm

Dates of Operation/Timeframe: The program began in 2012. It is a 9-week REU that takes place from early June through mid-August.

Background: The community college transfer pathway is particularly important for African American, Hispanic and Native American STEM degree recipients, as well as low-income students and recent immigrants. CCCS is the largest community college system in the U.S., serving 25% of the nation's community college students. The TTE REU program seeks to leverage the expertise of the three NSF-funded centers to provide interdisciplinary state-of-the art research experiences to community college students, thereby exposing these students to research at an early stage of their academic careers and helping to motivate them to continue in STEM while significantly improving their competitiveness as transfer applicants to selective four year universities.

Methodology: Education directors of three NSF-funded centers headquartered at UC-Berkeley begin meeting to plan the TTE REU program about six months prior to the grant submission deadline. By leveraging each Center's experience and resources, we mapped out a unique REU program that included a variety of interdisciplinary research opportunities as well as an array of enrichment opportunities, including a 40-hour lab bootcamp, group laboratory safety training, scientific ethics training, field trips, social events, and academic and professional development sessions carefully targeted to the needs of community college students. By bringing in UC-Berkeley TAP from the very start, we were also able to offer our students personalized state-of-the art transfer advising support not widely available to students at community colleges.

Impact/benefits: In our first year, the TTE REU program has been able to achieve the same extraordinary transfer success rate of other students served by TAP. Our students have been admitted to UC-Berkeley and other University of California universities at rates that are nearly three times the state average. We will continue to follow our students after transfer, with the goal of achieving graduation rates of >90%.

Evaluation/Assessment: TTE REU uses pre/post program student evaluations, mid-program and end-of-program mentor evaluations, weekly student reflections, and an exit interview with each student for assessment and feedback. All students are required to complete and present a research poster and a final (oral) presentation of their research results.

Sustainability: The program is funded by an NSF REU site grant and does not rely on ERC funding.

Tips: Because most community college students have never lived away from home, we have found that some participants may experience adjustment and time-management issues for the first few weeks of the program. Also, mixing younger students with older students (i.e. veterans, non-traditional or reentry students) can be challenging. It is helpful to have a cohort (however small) of each type of student.

4.4.5.2 ***Center*****:** Nanosystems ERC for Translational Applications of Nanoscale Multiferroic Systems (TANMS)
Lead Institution: University of California
Center Director: Prof. Greg Carman, Department of Mechanical and Aerospace Engineering
Name of Program: Engineering Research Experiences for Community College (eREC2)

Type of Program: Community college students REU

Program Synopsis: The eREC2 program targets community college students from underrepresented minorities (URM). The students work in a cohort under the mentorship of engineering undergraduate students who have research training. The cohort is also mentored by a graduate students as well as a Principal Investigator. The program starts with an introduction to the area of research interest and literature review, then the students (community college and university) work on a research problem together. At the conclusion of the program, the entire cohort prepares a poster, write a technical report and deliver an oral presentation to their peers, i.e. other community college students. The program introduce and sharpen students skills such as research, multiferroic, smart materials, troubleshooting, hands-on, design, system integration, oral and written communication, and teamwork.

Contact person/website: Mr. Enrique Ainsworth and Prof. George Youssef, http://www.tanms.ucla.edu/undergrad.htm

Dates of Operation/Timeframe: This program began in June 2013. It is a 10-week summer program of 25-30 hours per week.

Background: Community colleges (CC) are the gateway for many students into four-year universities, and a majority of post-secondary underrepresented minority STEM students is enrolled in community colleges. Students attend community college after high school for a number of reasons, including lower cost as compared to universities. Some students choose CC because they are uncertain about their career options and need the exploratory path; others may have low high school grade point averages that preclude their admittance to four-year universities.

Methodology: The eREC2 builds upon an existing STEM program between The Henry Samueli School of Engineering and Applied Science and three CCs, including two Hispanic Serving Institutions and one CC with a large number of minority students. The eREC2 leverages the 2yr/4yr partnership to target recruitment of underrepresented minority (URM) students with high interest in applying for REU research opportunities in TANMS partner universities.

Impact/benefits: The program provides a STEM education and career test run for community college students who may not realize that university research experience can increase their competitiveness for admission at selective universities, opening pathways for advanced degrees. The eREC2 program is especially important to first-generation immigrant and URM college students. It provides them with powerful academic and social networks not otherwise available to them and opens access to STEM professionals in academia and technology companies associated with TANMS. On a personal level, it helps students realize their capabilities and potential while building their confidence. The need for such a program is justified as the numbers of these student groups in advanced STEM fields are not commensurate with their numbers in the population. The complete talent pool must be tapped for the nation's continued advancement. eREC2 helps to produce an industry-ready, creative, innovative, and ethnically diverse workforce.

Evaluation/Assessment: Development of evaluation tools is in progress.

Sustainability: This program leverages existing programs at universities and community colleges to increase the number of students during the ERC maturity period, which will help continue providing opportunities after the Center graduates.

4.4.6 Competitions

4.4.6.1 ***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: International Genetically Engineered Machine Competition (iGEM)

Type of Program: International undergraduate competition in synthetic biology

Program Synopsis**:** iGEM is the premiere undergraduate competition in the field of synthetic biology, founded at SynBERC partner institution MIT with funding from SynBERC. Student teams are given a kit of biological parts at the beginning of the summer from the Registry of Standard Biological Parts. They work at their own schools over the summer, using these parts and new parts of their own design to build novel biological systems and operate them in living cells. This project design and competition format is an exceptionally motivating and effective teaching method. In 2011, iGEM expanded to include a High School Division; an Entrepreneurship Division was added in 2012.

Contact person/website: Meagan Lizarazo (meagan@igem.org) , http://igem.org/Main_Page

Dates of Operation/Timeframe: iGEM takes place from May through November of each year. Team members work an average of 40-60 hours per week during the summer.

Background: iGEM is dedicated to education and competition, advancement of synthetic biology, and the development of open community and collaboration through establishing and operating the Registry of Standard Biological Parts, a community collection of biological components.

Methodology: Major funding from SynBERC enabled a five-school design contest started at MIT in the summer of 2004 to grow into an international competition with 245 teams and over 2,000 students, faculty and instructors. iGEM outgrew its home base at MIT in 2011 and transitioned to an independent nonprofit organization called the iGEM Foundation. In 2011, the iGEM High School Division was initiated with 40 high school teams. In 2012, a pilot program for the iGEM Entrepreneurship Division was launched. 15 teams registered, competing in areas such as Business Plans, Economic and Business Models, Industry Development, Business and Regulation. Team members ranged from undergraduate students in science and engineering to law students and social scientists. Also in 2012, the iGEM Labs program was launched. This program provides academic labs with access to the same resources as iGEM competition teams, but allows participants to work on projects over a longer period than an iGEM competition team season. To date, over 200 academic research labs have registered for iGEM Labs.

Impact/benefits: Thousands of undergraduates participate in iGEM each year, making iGEM the largest synthetic biology training program in the world. As the competition has grown, the success of the student projects has dramatically increased, as has the intensity with which students devote themselves to their projects. iGEM has had a major impact on students who join the synthetic biology community as a result of their participation, as well as on the professors and instructors who take part in the competition and all the institutions involved. iGEM also exposes the general public to synthetic biology and has an impact on public perception of the field as a whole. Finally, iGEM promulgates safe and sustainable practices within synthetic biology labs around the world.

Evaluation/Assessment: iGEM collects participant feedback through web surveys disseminated to all participants, including students, instructors, and judges. The data is analyzed by iGEM leadership and incorporated into program planning and improvement. Through direct and ongoing contact with stakeholders at iGEM meet-ups, Jamborees, and training sessions, iGEM staff and leadership solicit advice, ideas, and feedback.

Sustainability: As SynBERC funding decreases, the iGEM Foundation has initiated an aggressive campaign to solicit increased funding from alumni, corporate sponsors, registration fees, and government grants.

Tips: While growth and impact has far exceeded expectations, it has been extremely challenging to provide infrastructure and support to iGEM teams and participants worldwide while still maintaining a healthy bottom line.

The International Genetically Modified Machines (iGEM) competition continues to expand its reach, with 130 teams and nearly 2,000 students, faculty and instructors attending the November 2011 event at SynBERC partner the Massachusetts Institute of Technology. (Credit iGEM and Roel ten Hagen–Permission from iGEM)

4.4.7 Programs for Veterans

4.4.7.1 ***Center:*** ERC 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 Veterans -University Projects (REV-UP)

Type of Program: Research experiences for targeted groups (in this case, veterans) [funded under the Veterans Research Supplement (VRS) program]

Target Population: Undergraduate, graduate, or community college students who are veterans

Program Synopsis: CSNE sponsors a summer research program for veterans on the University of Washington's (UW) Seattle campus. Participants work with investigators on ongoing research projects and take part in training sessions designed to provide undergraduate scientists with solid critical thinking and communication skills that will serve as a foundation for future study.

Contact person/website: Dr. Lise Johnson, CSNE Education Manager (liseaj@uw.edu), http://www.csne-erc.org/research-experience-veterans

Dates of Operation/Timeframe: The program began in February 2013 with two months of recruitment effort (two hours per week). Applicant review and selection occurred in spring 2013 (ten hours), and the ten-week research experience program began on June 17th (ongoing support to participants, staff and faculty).

Background: CSNE researchers understand that increasing numbers of student veterans are enrolling in postsecondary institutions, but are underrepresented in STEM programs. Further, they believe that the field of sensorimotor neural engineering would be of particular interest to veterans, since many veterans have worked with technology during their service as well as are aware of injuries sustained by veterans that this emerging technology will address. Working with veterans is especially salient to CSNE because partner campuses are located in proximity to large military bases and facilities. As stated in the Report of the National Science Foundation Workshop on Enhancing the Post 9/11 Veterans Education Benefit (*http://www.nsf.gov/eng/eec/VeteranEducation.pdf)*, "Post-9/11 veterans include a diverse and qualified pool of future talent for the nation's engineering and science employers. Ushering them into technical fields as workforce-ready engineers and scientists will require a community of partnerships among the veterans themselves, the nation's educational institutions, technology firms, the government's technical and scientific organizations, and others."

Methodology: Beginning in February 2013, the CSNE Education Manager worked with CSNE staff and partners to develop and disseminate recruitment materials, including a promotional flyer and a REV-UP website. Allies were identified to help design recruitment materials and form the structure of the REV-UP program, which included a veteran STEM faculty member, the director of the Veterans Training and Support Center, the director of the UW campus Veterans Center, student veterans participating in a UW student group called Husky United Military Veterans, and veteran-serving members of an online "community of practice." Applications were due at the end of March, and a panel of CSNE staff members selected candidates in April. It was determined that the first year pilot REV-UP program would support two participants. After they were selected, the CSNE staff worked with laboratory personnel and principal investigators to determine the best fit regarding lab placements and research experiences. The ten-week research program began on June 17th. Participants worked in the laboratory of a CSNE researcher and were mentored by a graduate student, a postdoctoral trainee, and a professor. They worked with their teams on projects with defined goals that were approved by the CSNE and had a significant interdisciplinary component. Participants also attended lectures and seminars on relevant topics and participated in a poster session and a research symposium where they presented their work.

Impact/benefits: On April 27, 2009, in a speech to the National Academy of Sciences, President Obama called for major investments in attracting students to science and engineering, because science is now "more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before." Further, as stated in the Report of the National Science Foundation Workshop on Enhancing the Post 9/11 Veterans Education Benefit, "there is a coming shortage in the U.S. engineering and science workforce. The cause is a downward trend in student interest in engineering and science and the expected retirement of large numbers of engineers and scientists during the coming decade." and "many of today's service members have an interest in and talent for technical fields… Unfortunately, interest and talent do not always translate into careers in engineering and science. Only a small percentage of recent veterans have taken technical jobs." It is believed that the CSNE REV-UP program will help to draw veterans into technical fields of study and enrich their educational experience and help them to start their new careers in engineering and science.

Evaluation/Assessment: The CSNE contracts with external education evaluators at the Center for Research and Learning. These evaluators designed and administer a post-program survey. The survey measures the program's impact on the CSNE target skill-sets and attempts to capture the participant's perceived benefit and the program's impact on their future educational and career plans.

Sustainability: CSNE staff members are working to identify supplemental funding opportunities from the National Science Foundation and other sources.

Tips: It is important to cast a wide net with recruiting efforts and be very explicit about program commitments. CSNE staff and allies noted that student veterans are more likely than their undergraduate peers to have jobs, have a family, live off campus, and be involved in other benefit programs and medical appointments. It is important to solicit as many applications as possible and work with military-serving organizations in order to generate a viable pool of candidates.

4.4.7.2 ***Center*****:** ERC for Quality of Life (QoLT)
Lead Institution: Carnegie Mellon University
Center Director: Dr. Dan Siewiorek; home dept.: HCII: Human Computer Interaction Institute
Name of Program: Experiential Learning for Veterans in Assistive Technology (ELeVATE)

Type of Program: Transition program for veteran undergraduate students in STEM

Target Population: Post-medical rehabilitation wounded, injured, or ill veterans

Program Synopsis: ELeVATE is designed to re-integrate veterans to college. Participants complete a ten-week paid research experience, including a team project, learning 21st century skills in workshops, and preparing to begin classes at a college of their choice. ELeVATE participants work closely with vocational coordinators to assure that adequate supports are in place for their academic success. During this time, ELeVATE students are offered housing and other family assistance. Participants continue to refine their academic interests and apply for a formal program at the University of Pittsburgh or another institution of their choice. Participants enroll in the university and prepare to graduate from the ELeVATE program. However, the support system does not end here—ELeVATE students stay connected to their cohort through study groups and other support groups. Program participants are encouraged to remain connected to the program by serving as mentors to new ELeVATE participants.

Contact person/website: Mary Goldberg (mrh35@pitt.edu), www.qolt.pitt.edu

Dates of Operation/Timeframe: The program takes place each summer from the end of May through the first week of August.

Background: After incurring injuries, wounded, injured, or ill (WII) warriors in military treatment facilities receive excellent medical care. To move from medical rehabilitation to vocational rehabilitation, and transition from being service members to veteran status, they need access to future opportunities to successfully reintegrate into the civilian community. Exposure to higher education opportunities at this stage provides veterans powerful motivation to complete the initial stages of their rehabilitation. As President Obama stated about the GI Bill, we are indebted to those who have served our country and must invest in them for the good of our country's future as a whole. Engineering programs, especially in domains like assistive technology design and development, provide technical preparation for well-paying jobs at the bachelor's degree level and provide solid preparation for many graduate programs (e.g., advanced engineering degrees, rehabilitation science and technology, MBA). The ELeVATE program provides year-long program support, internships, innovative networking, and external relationship-building with professionals in the community to its WII veteran participants.

Methodology: We received a grant from the NSF Research in Engineering Education (REE) division. We run the program collaboratively with two REU programs and an internship program supported by the National Collegiate Innovators and Inventors Alliance (NCIIA). Students from all internship programs benefit from all of the programs' workshops and seminars.

Impact/benefits: ELeVATE directly addresses two key societal issues of great importance in the United States: a) the effective transition and support of veterans with disabilities in to engineering and technology disciplines, resulting in degree attainment and gainful employment; and b) the shortage of trained STEM professionals. We are indebted to the veterans who have made sacrifices for our country and fund veterans' education through the GI Bill. As more WII veterans return from current conflicts, we expect to see an influx of non-traditional, veterans with disabilities (VWD) in higher education. However, without an effective transition and support structure, these veterans may not persist at the same rate as their non-disabled and non-veteran peers. Our goal is to extend the continuum of rehabilitative care for

VWD to a comprehensive vocational rehabilitation program designed to prepare them for successful integration into engineering and technology higher education programs, and to create a best practice model that will be disseminated to our partners and other interested parties nationally. ELeVATE produces systematic changes in the educational preparation and experience of VWD in engineering and technology by: a) providing interventions targeting not only VWD but their support systems, including mentors and university faculty and staff; b) providing a comprehensive rehabilitation support system of practitioners and resource centers; and c) disseminating best practices for attracting and retaining VWD through expansion and replication. The program also addresses the needs of students with disabilities in STEM. One of the issues related to the shortage of STEM professionals is that the rates of underrepresented students in these fields remain critically low, including students with disabilities who have issues similar to VWD.

Evaluation/Assessment: Theoretical frameworks, information on the types of data collected, and statistical analysis is included in the table below. Identical data is collected from the participant and control groups and used to evaluate each hypothesis. Baseline data collection includes the Fundamentals of Engineering (FE), Longitudinal Assessment of Engineering Self Efficacy (LAESE), academic data, transition questionnaire, etc. After a subject completes three rounds of data collection (baseline, end of first semester, end of second semester), follow-up data collection points for both subject groups occur every 12 months. The only data that is collected on the intervention group and not the control group are: a) baseline measurements at the beginning of the ELeVATE program to effectively compare pre-/post-and/or immediate gains; and b) attendance and involvement in follow up activities.

Theoretical Framework	Characteristic(s) Measured	Measurement Approach
	Math skills	University of Pittsburgh preliminary math assessment
Experiential Learning (EL), Reflective Learning	ABET hard skills criteria: a, b, c, e, k	Sample questions from the FE exam; STEM course grade GPA
EL, Social Cognitive Career Theory (SCCT)	ABET soft skills criteria: d, f, g, h, i, j	Global Preparedness Index
Student Engagement theory	Reintegration	28-item National Survey of Student Engagement (NSSE)
SCCT, self-efficacy	Long-term goal setting, self-awareness	48-item LAESE
	All of the above	Quantifiable achievement tracking (one point for each indicator): peer-reviewed publications, best paper awards, conference presentations, fellowship awards, student group involvement, subsequent research experience, internships, job interviews, job offers, graduate school applications & acceptances

Sustainability: We received a grant from the NSF Research in Engineering Education (REE) Division.

Tips: Though we do not limit participation to those veterans who have gone through Warrior Transition Units (WTU) or Wounded Warrior Regiments (WWR), we do devote special effort in recruiting them for ELeVATE. Interested parties apply online via our ELeVATE website. We market our program to the WTU and WWR through the Commanders, Sergeant Majors, Career Counselors, and other leaders. Our intent is to identify service members while they are leaving the service, or have just have left the service, as we know they make post-military career decisions one to two years prior to retirement or discharge (another item that was derived from our needs assessment). We are also linked to national veteran organizations with local chapters in Pittsburgh, such as Paralyzed Veterans of America and Disabled American Veterans. We participate in workshops at Pitt, Carnegie Mellon University (CMU), and Community College of Allegheny County (CCAC) to inform veterans about educational options, which also serves as recruitment tool for future cohorts.

A sample schedule is included below:

Day	Time	Activity	Tasks completed	Personal outcomes or skills gained
Mon	0800	Meet with rehabilitation counselor	Weekly check-in	Accountability, stronger sense of self
	0930	Meet with mentor	Provide progress report on research project	Responsibility, professional communication
	1030	Meet with research team	Provide updates to team on individual progress	Knowledge of research project goals-link to the bigger picture
	1300	Work in lab	Assist in fabrication of wheelchair component	Technical/machining skills
Tues	0800	Work in lab	Review research protocol for preparation of subject testing	Reading comprehension
	1000	Meet with graduate student mentor	Review procedures for subject testing	Professional communication
	1100	Assist graduate student mentor with subject testing in clinic	Communicate with subjects, set up tests, administer questionnaire	Interpersonal communication, how to act in professional manner in clinical setting
	1400	Work in lab	Upload data from subject testing	Organizational skills, database management
Wed	0800	Work in lab	Analyze data with statistical software with assistance from graduate student mentor	Math/statistics skills, increased analytical capacity
	1300	Work in lab	Incorporate results in to research paper	Writing skills, research skills
Thurs	0900	Weekly writing seminar	Provide others with feedback on their research papers, gain feedback from faculty instructor about newly incorporated "results" section completed this week	Analytical skills, professional communication, writing skills, presentation skills
	1300	Work in lab	Incorporate feedback in to paper	Writing skills
	1500	Digital media design	Learn fundamentals of design	Presentation skills

		workshop	to enhance presentations and reports	
Fri	0900	Weekly program meeting	Discuss issues and roadblocks; complete transitional workbook module of week: “Matching a career/job to you” as group	Vocational rehabilitation, interpersonal communication, articulating and managing goals
	1300	Weekly math and statistics seminar	Complete individual module of week; discussion problems; present examples from individual paper for questions and feedback	Math and statistics skills, problem solving

U.S. Army veteran and University of Pittsburgh student Nathan Bastian(shown) worked on the design of this special “throwing chair” that will be used by disabled veteran athletes during events such as the National Veterans’ Wheelchair Games. He participated in the Experiential Learning for Veterans in Assistive Technology and Engineering program (ELeVATE), coordinated by the Quality of Life Technology Center. (Credit: QoLT)

4.4.8 Programs for Students with Disabilities

4.4.8.1 ***Center*****:** ERC for Quality of Life (QoLT)
Lead Institution: Carnegie Mellon University
Center Director: Dr. Dan Siewiorek; home dept.: HCII: Human Computer Interaction Institute
Name of Program: The Quality of Life Technology Enrichment (QuOTE) Project

Type of Program: Transition program including course development for undergraduate students with disabilities

Program Synopsis: In preparation for providing greater support to recruit and retain students with disabilities (SWDs), we created a system to collect and analyze data on SWDs at the University of Pittsburgh (Pitt). We used that information to develop curricular materials for undergraduate students and training materials for mentors. We facilitated a semester-long one-credit course for undergraduate students to support their transition to and out of STEM degree programs. This course links SWD students to mentors through an online platform. The mentored relationship extends past the end of the course and through the students' academic careers.

Contact person/website: Mary Goldberg (mrh35@pitt.edu), www.qolt.pitt.edu

Dates of Operation/Timeframe: We started this program in January 2013. The course will run in the fall semesters and the mentor program will be year-round.

Background: Acquiring a bachelor's degree is a prerequisite to many career opportunities. Numerous studies found employment rates for people with disabilities have a stronger positive correlation with the level of education than appears in statistical trends for the general population. However, SWDs tend to choose two-year community colleges or vocational schools over four-year colleges. Of those enrolled in some form of postsecondary education, 42% of SWDs are enrolled in four-year colleges as compared to 62% of those without disabilities. Many of these community college SWDs have the desire and potential to transfer to four-year colleges but face challenges in making a successful transition. A survey study with faculty/staff members and SWDs at two-year and four-year institutions identified the top concerns about transferring to a four-year college. Some of these concerns are similar to those faced by their peers without disabilities (e.g., changes in academic requirement, poor study skills, and inadequate financial support). Other concerns are related to their disabilities. For example, students may lack skills in self-advocacy and have difficulty adjusting to the differences in disability services between the two types of schools. All factors are considered in designing our interventions to transition SWDs to four-year universities. An important focus of our effort is to transition SWDs to graduate schools. With the global competition and shift to a knowledge-based economy, graduate education is growing in importance. According to the report, "The Path Forward: The Future of Graduate Education in the United States", advanced degrees will be required for an estimated 2.5 million new jobs by 2018. The Bureau of Labor Statistics estimates that jobs requiring master's degrees will grow by 18% from 2008 to 2018. Unfortunately, our investigation found that little attention has been directed on transitioning SWDs to advanced degrees. A report evaluating NSF's Research Experiences for Undergraduates (REU) programs showed that, 37% of students went into the program expecting that a bachelor's degree would be the highest they would obtain. After their REU experience, that number decreased to 14%. Our experience showed that the REU type of internship programs are also effective to advance SWDs to graduate schools, especially if they are matched with faculty mentors who have a disability or understand disability issues. Many of our faculty in the QoLT ERC have knowledge of disability conditions as well as experience working with graduate SWDs. This lays a good foundation for implementing interventions to transition SWDs to graduate schools.

Methodology: This project involved constructing a new infrastructure to determine the enrollment number, retention rate, and graduation rate of SWD in STEM disciplines at both the undergraduate and graduate levels at Pitt. It also involved mining current institutional databases to collect additional student data (major, enrollment dates, transfer and/or graduation dates, where applicable) to add to the database that the Office of Disability Resources and Services currently maintains. We surveyed current SWDs and alumni from Pitt to identify specific success strategies and barriers in the campus environment here. We connected with the Pitt Student Disability Advocacy group to assist in drafting the survey through a preliminary needs assessment and later review of the draft. Lastly, we developed a course to support SWDs' transition to the university by teaching self-advocacy techniques and exposure to career opportunities in STEM. We have also recruited mentors for the course and prepared training modules that include material developed by previous/current NSF disability alliances. The mentors will access the training materials on the same learning management system (LMS) prior to their involvement in the course to become certified.

Impact/benefits: The use of an online infrastructure allows us to easily disseminate course content that incorporate the principles and materials QoLT developed under this grant to faculty at two-year colleges and four-year universities nationwide. In addition, the outcomes of the project will be made available to all institutions nationwide through distribution to existing Alliances for Students with Disabilities. This project allows us to build a collaborative relationship with community colleges, the University of Pittsburgh, Carnegie Mellon University, and other to-be-named partners that will serve as a national model for programs for students with disabilities in STEM, especially those enrolled in engineering and technology disciplines.

Evaluation/Assessment: The measures used for objectives relating to gathering and analyzing data are: a) the amount and completeness of the data obtained from Pitt; b) the readiness of the data collection and tracking process for annual updates; c) the amount of resources identified that can directly help QuOTE intervention development; d) the relevance and usefulness of the report describing the identified facilitators and barriers in guiding the QuOTE intervention development; and e) the readiness of the data collection system to be replicated or adapted by other institutions, such as CMU.

Sustainability: We received funding from NSF Research in Disabilities Education (RDE) program to support this project.

4.4.9 Industry Internships

4.4.9.1 ***Center*:** ERC for Compact and Efficient Fluid Power (CCEFP)
Lead Institution: University of Minnesota
Center Director: Dr. Kim Stelson, Department of Mechanical Engineering
Name of Program: Fluid Power Scholars Program

Type of Program: Undergraduate internship program with industry

Program Synopsis: This program provides a “scholarship” in the form of four-day training in fluid power that is paid for by CCEFP. CCEFP recruited 10 people from industry to propose internship experiences in their companies that are aligned with the Center’s work. CCEFP recruits, selects, and hires candidates with the most potential to serve as summer interns. CCEFP offers provides recruiting services as well as sponsors a four-day fluid power training at Milwaukee School of Engineering (MSOE) at the outset of the internship. Over 67% of participants have become full-time employees. Several have returned for a repeat internship. Most continue into graduate school. This program is a strong element of the Center’s sustainability plan.

Contact person/website: Alyssa A Burger, Education Outreach Director (Alyssa@umn.edu), www.ccefp.org

Dates of Operation/Timeframe: This program was launched in 2010, the Center’s fourth year. It is a year-round activity, although the internship occurs during the summer. The greatest amount of time is spent recruiting companies to participate. There are many barriers specific to each company, and a relationship is needed to overcome those barriers.

Background: The greatest asset of the CCEFP to the fluid power industry is our intellectual capital and the synergy between academia and industry (i.e., direct access to potential talent). The industry needs talent trained in this field. For many years, we attempted to ask industry to let us help them find talent. The challenge has been that most companies have their own recruitment infrastructure. We had to offer something unique. The element we could provide to the corporate members were trained students, so by offering a scholarship to attend an intensive training program, we ensure all students going into internships have a basic knowledge of hydraulic and pneumatic technology. The Fluid Power Scholars Program was born.

Methodology: a) Identify the program concept and value statement. b) Recruit companies (most difficult) and students (easy—replicate the REU approach). c) Implement a web portal for companies to post internship positions and for students to apply. d) Implement a web portal for companies to view all applicants, select top candidates, interview, and hire. e) Assist in coordinating the Fluid Power Scholars Bootcamp at MSOE and pay for attendance. f) Conduct pre- and post- surveys and tracking.

Impact/benefits: The fluid power industry is enormous. Unfortunately, hydraulic and pneumatic technology is not taught in the general undergraduate mechanical engineering curriculum (except at CCEFP schools), so much of those entering the industry are not trained. Industry generally spends one to two years training a newly hired engineer. The CCEFP can assist in reducing training effort by providing industry with employees or interns who are ready to work upon hire.

Evaluation/Assessment: The CCEFP uses pre- and post- surveys as well as personal interview with interns and their corporate mentors or supervisors. The Center's evaluation team also conducts sponsor studies to determine where the industry primary pulse lies, i.e., in the development of people or in the development of research and innovation.

Sustainability: This program has a small budget, currently less than $10,000 (essentially $1,200 per student participant). Industry plays the greatest role in the CCEFP's sustainability plan. This program, along with others in the CCEFP Education and Outreach (E&O) Program Portfolio, will be part of our value statement to industry when recruiting continuation support. This program has one of the highest likelihoods of sustainability in the future because of the direct and obvious benefit to our stakeholders.

Tips: Establishing a relationship with the correct contacts is the most difficult, but most rewarding activity. Navigating the company infrastructure and reaching the appropriate people is a challenge. For example, in a company like Caterpillar, Inc., our corporate contact may not be affiliated with the human resources personnel we may need to know in order to implement this program. At the same time, HR personal may not know about CCEFP, making it hard to get their attention. We need our Industry Advisory Board (IAB) representative to connect all those dots, and some are willing while others are not. The Center's ILOs need to be part of the process to help gain traction with industry stakeholders. Also, anything in its early stages is difficult. It took one year to gain support, and now industry seeks us out and most are repeat participants.


CCEFP undergraduates offer a vital resource to the fluid power industry through internships as Fluid Power Scholars.

4.4.10 Collaborations with Diversity and Other Programs

4.4.10.1 ***Center*:** ERC 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: Partnership for STEM student support and success program

Target Population: Undergraduate students

Note: The MESA program serves K-12, community college, and university-level STEM students from diverse backgrounds. It is described in detail in example 4.3.10.1 under Diversity Programs, in the appendix to sec. 4.3-Precollege Programs.

4.4.10.2 ***Center:*** Georgia Tech/Emory Center (GTEC) for the Engineering of Living Tissues, a graduated center (1998–2008)
Center Director: Dr. Robert Nerem, Chair for Engineering in Medicine
Name of Program: Partnership to produce a new generation of African-American tissue engineers

Type of Program: Involvement of underrepresented students in research

Program Synopsis: The Georgia Tech/Emory Center (GTEC) for the Engineering of Living Tissues formed a partnership with the Atlanta University Center (AUC), a consortium of Historically Black Colleges and

Universities (HBCUs) in the city of Atlanta, to educate a new generation of African-American tissue engineers through involvement in research.

Contact person/website: Ms. Megan McDevitt (megan.mcdevitt@ibb.gatech.edu)

Dates of Operation/Timeframe: The program was started in 2003 and operated year-round through 2008.

Background: The ranks of scientists and engineers on university faculties and in industry still do not reflect nearly enough the talent available within underrepresented minority groups in the U.S. This is especially true of new fields such as tissue engineering, where students from smaller schools don't have access to the necessary research opportunities and facilities. This ERC leveraged its proximity to numerous predominantly African-American institutions of higher education by forming an active partnership with a consortium of HBCUs.

Methodology: To help address this shortcoming, GTEC and AUC formed a partnership that: (1) provided seed grants to Morehouse School of Medicine junior faculty for collaborative research with GTEC faculty; (2) funded research internships in the GTEC laboratories for AUC undergraduate students; (3) mentored and advised AUC students to promote their matriculation to Georgia Tech for engineering degrees; and (4) supported research internships for AUC faculty at GTEC to enhance their research opportunities through the use of state-of-the-art equipment and inclusion in research projects and publications.

Impact/benefits: The partnership will provide benefits in research and education for faculty and students from the HJBCUs, Georgia Tech, and Emory University School of Medicine. It will enable GTEC to increase the minority faculty and student involvement in its programs and include more biologists and clinicians in those programs as it addresses the challenges of tissue engineering.

An example of the impact of this program is seen in Manu Platt. Dr. Platt received his Bachelor of Science degree from Morehouse College in 2001. While he was an undergraduate he was invited to carry out research at GTEC under this program, as a part of the GTEC team. As a result, he decided to pursue a Ph.D. in biological engineering at Georgia Tech. He completed his doctoral degree at GTEC in 2001 and became a postdoctoral fellow at MIT's Biotechnology Process Engineering Center (BPEC), then a graduated ERC. In early 2009, Dr. Platt returned to Georgia Tech to join the Biomedical Engineering faculty, where he is affiliated with GTEC and is continuing his research on methods to improve the growth, differentiation, and survival of adult stem cells using specially treated biological scaffolds. He is also active in mentoring biomedical engineering students.

Evaluation/Assessment: Not available

Sustainability: Not available

Tips: Not available

Professor Manu Platt (left) works with Randy Ankeny, formerly a GTEC Research Experiences for Undergraduates student and at that time a student in the Bioengineering PhD program at Georgia Tech.

4.4.11 Undergraduate Outreach to Precollege Students

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

Type of Program: Undergraduate outreach/mentoring to precollege students

Program Synopsis: The RPI Engineering Ambassadors program was developed to support the overall mission of pre-college education outreach for the School of Engineering, including the Smart Lighting ERC. It has two main goals: a) to help Rensselaer undergraduate students develop excellent communication skills by giving them the training and opportunity to teach engineering technology to younger audiences of middle and high school students; and b) to inspire K-12 students to pursue academic degrees and careers in engineering by showing them that engineers solve critical problems that affect the quality of life, health, and safety of society. The program is supported through corporate funds, faculty efforts, ERC precollege funding, RPI undergraduate research program (URP) match funding, and private grants.

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

You Tube: RPIEngAmbassadors

Note: For further details on this program, see example 4.3.5.2 in the appendix to sec. 4.3, Precollege and Community Engagement

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, which included extensive communication training, Assertion–Evidence presentation style, and creative hands-on activities. The Rensselaer program has grown from four students in spring 2011 to approximately 30 undergraduate students in the fall of 2013. The program runs throughout the academic school year and requires a commitment of 30–60 hours per semester for each EA, depending on student academic workload for which the students are paid a stipend.

The Engineering Ambassadors were trained by Smart Lighting ERC faculty and students when they developed the first versions of their outreach activities.

Methodology—Preparing Engineering Ambassadors for the K–12 Classroom: Undergraduates are selected through a competitive recruitment process that looks for students with strong academic standing and a passion for education outreach. During the general EA recruitment process, students are introduced to the Smart Lighting ERC and asked to consider supporting the Center's education outreach mission. In order to sustain the ERC's presence within the RPI EA program, there are at least 3–4 students identified each semester to support the ERC mission. Thus, there are always three or four Smart Lighting grad students involved as mentors but they are not ambassadors. Like most other outreach operations, we find it best to have undergrads work with high school students. Upon acceptance into the program, the undergraduates form teams of two or three students, identify a technical faculty advisor (the ERC's Education Director, who is a faculty member), and are scheduled to participate in an intensive 3-day communications training session. During the training workshop, the EAs develop an engaging technical presentation such as the Smart Lighting ERC "Future of Light" that supports the findings of the National Academy of Engineering (NAE) Report, *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. EAs practice and fine-tune their presentations and develop complimentary hands-on activities. Once complete, the EA presents the material to their technical advisor and the Education Outreach Director and peer EAs for critique prior to taking the show on the road.

The RPI Engineering Ambassador network connects with local urban, rural and suburban school district to schedule school-wide visits. Typically four to five EA teams representing different engineering topics travel to 12–14 regional school districts each academic year. During each visit, an individual EA team presents up to four times within school districts' classroom schedule, exposing approximately 320 precollege students to engineering during one school visit. This infrastructure of a well-prepared EA army of undergraduates travelling to regional school districts can conservatively expose 3800 precollege students to "Better World Engineering."

***Impact/ Benefits*:** The RPI Engineering Ambassadors program has been an effective tool for spreading the messages in 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 the undergraduates and their presentations.

There have been 7 EAs (ME, EE) involved with the Smart Lighting ERC EA presentation, "Future of Light", since the program's inception in 2011. Over the 6 semesters, the "Future of Light" presentation has been presented to approximately 70 middle or high school classrooms, engaging over 1400 students on the attributes of digital lighting.

The RPI EA program proves to be beneficial experience for the young audience members and undergraduate presenters while effectively supporting the ERC's precollege education outreach objectives.

***Evaluation / Assessment*:** Formative and summative assessments are conducted at several phases of the program, including recruitment, internship training, and post-internship follow-up. To assess the experience from the perspective of faculty advisors and student mentors, a separate survey is administered at the end of the program. All surveys are web-based and allow for direct data entry, ease of tracking program outcomes, and electronic storing of the data. 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 presentations given during the inaugural year 2011-2012. The 2011-2012 cohort of 20 Rensselaer Engineering Ambassadors were surveyed and interviewed. The outcomes included:

- 72% agreed that the presentation had helped them learn to transfer information outside their area
- 83% agreed that they were more motivated to learn the course content
- 83% agreed that the process had helped them develop self-direction and responsibility

94% agreed that the process helped them to develop confidence in presenting engineering content. These preliminary results suggest that the Engineering Ambassador program is effective and beneficial; however, further studies need to be conducted to substantiate the results.

In 2013 the program organizers realized that the informal mentoring of the Engineering Ambassadors by ERC students was working well, but that the overall student experience would be improved by the following changes:

a. Have the ambassadors present their activity to a small group of ERC grad students at least once each year to monitor the accuracy of the story they tell and to provide ideas for continuous improvement.

b. Add a position on the Student Leadership Council for an ambassador and possibly one additional undergrad who is involved in a research or design project. The present SLC membership is essentially all grad students.

c. Identify at least two internships for undergrads with the ERC's industry partners. The people we work most directly with from our partners are generally more interested in grad students, but internships are a major draw for the ambassadors and we are losing out by not connecting them with industry.

d. Have the ambassadors put their activities in the format of one of our educational modules, with help from a grad student partner.

Sustainability: Rensselaer has successfully integrated the program into our research landscape, so the program has also been a useful method for faculty and/or research centers to share the importance and benefits of cutting edge research and the overarching purpose of a research effort. The program is funded by the National Collegiate Innovators and Inventors Alliance (NCIIA).

Tip: Pairing internship programs (e.g., REU and internal programs sponsored by the business school) allows for cross-disciplinary collaboration and leveraging of funds.

4.4.11.2 ***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: Outreach tool developed by ERC students

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. One of the purposes of the competition was to develop new education and outreach tools. The projects, which were required to clearly illustrate principles of sensorimotor neural engineering, were also intended to become demonstrations for informal science outreach events. All the projects were successful, but the winning project, WrestleBrainia3000 (WB3K), has proved to be an incredibly 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. Almost everyone who plays tries harder than they thought possible and wears a huge grin when they're done. 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.

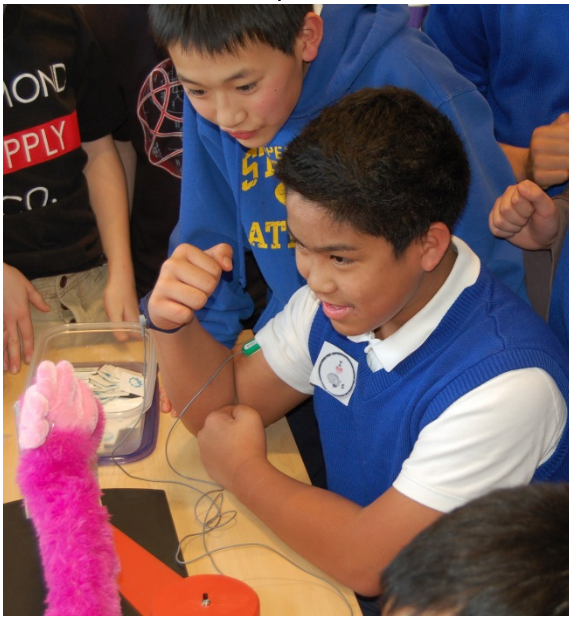
Since EMG signals depend less on total muscle size than on skin conductance, muscle fiber recruitment, and effort over baseline, smaller and weaker players can compete with larger, stronger players. This means that kids can beat grownups, non-athletes can beat jocks, and anyone who tries hard has a decent 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. WB3K, developed by CSNE students, has helped showcase the talents of CSNE students and raise public awareness of the potential of neural engineering to create fun games, transform the human-computer interface, and provide life-changing assistance to people suffering the devastating effects of stroke, Parkinson's disease, and spinal cord injury. We expect that thousands more players will try the game in the coming years.

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 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)