Developing Changemaking Engineers – Year Three

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Susan M. Lord received a B.S. from Cornell University and the M.S. and Ph.D. from Stanford University. She is currently Professor and Chair of Electrical Engineering at the University of San Diego. Her teaching and research interests include electronics, optoelectronics, materials science, first year engineering courses, feminist and liberative pedagogies, engineering student persistence, and student autonomy. Her research has been sponsored by the National Science Foundation (NSF). Dr. Lord is a fellow of the ASEE and IEEE and is active in the engineering education community including serving as General Co-Chair of the 2006 Frontiers in Education (FIE) Conference, on the FIE Steering Committee, and as President of the IEEE Education Society for 2009-2010. She is an Associate Editor of the IEEE Transactions on Education and the Journal of Engineering Education. She and her coauthors were awarded the 2011 Wickenden Award for the best paper in the Journal of Engineering Education and the 2011 and 2015 Best Paper Awards for the IEEE Transactions on Education. In Spring 2012, Dr. Lord spent a sabbatical at Southeast University in Nanjing, China.

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Michelle Madsen Camacho is Professor and co-PI on the NSF-sponsored grant, "REvolutionizing Engineering and Computer Science Departments" (RED) at the University of San Diego. She is a former Fellow of the American Council on Education. Her research focuses on inequities in STEM education using quantitative and qualitative research methodologies and theories from interdisciplinary sources including cultural studies, critical race, gender and feminist theories. Her book, the Borderlands of Education, is co-authored with Susan Lord, Professor of Electrical Engineering. Camacho is affiliated faculty with the Department of Ethnic Studies, Women's and Gender Studies, and the School of Peace and Justice. On the RED grant, her work focuses on the mechanisms that produce organizational transformation.

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Dr. Leonard Perry (ISE) has research interests in the area of system improvement via quality improvement methods especially in the area of applied statistics, statistical process control, and design of experiments. Dr. Perry consults, instructs, and collaborates on quality improvement projects with representatives from biotech, health care, defense, and traditional manufacturing institutions. He has been an instructor for the Six Sigma Black belt training at the Six Sigma Institute for three years. He is a UCSD Certified Six-Sigma Master Black-Belt and an ASQ Certified Quality Engineer.

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Abstract

This paper describes progress to date resulting from a National Science Foundation (NSF) IUSE/PFE Revolutionizing engineering and computer science Departments (RED) grant. Traditionally, engineering students are trained technically, with less focus on critical examinations of assumptions within engineering practice, and less emphasis on the larger contexts in which engineering is embedded. With funding from this RED grant, our School of Engineering is working to produce and disseminate a model for redefining the "engineering canon" with the goal of developing "Changemaking Engineers". This revised canon teaches technical skills within a contextual framework that includes humanitarian, sustainable, and social justice approaches. This requires an enhanced curriculum that also includes a focus on student teamwork, a greater consideration of social and economic factors, improved communication with diverse constituents, and reflection on an ethical understanding of decisions and solutions. This broader perspective of engineering practice will produce graduates who can address a wider range of societal problems bringing new perspectives to traditional areas.

In this paper, will review our efforts towards achieving this vision, including:
- Establishing a foundation for a revised engineering canon.
- Developing a faculty that embraces the redefined engineering canon and the professional spine.
- Establishing partnerships to develop a culture of change within the school and developing professional skills including greater connections between technical knowledge and professional practice through an industry-developed "Industry Scholars Program.
- Developing a new "General Engineering" department as an incubator of RED curriculum staffed with cluster hires around the RED proposal themes.

Establishing a foundation for a revised cannon

One of the goals of the NSF RED grant is to: *"Develop the foundation of a revised engineering canon and empower faculty to develop and deliver a professional spine that prepares changemaking engineers."*

Establishing a foundation for a revised engineering canon includes the development of courses that include transferable content (e.g. modules) that contextualize engineering through social justice, humanitarian practice, peace, and sustainability. The three courses supported through the RED grant in year three include:

- *Engineering Peace with Drones*
  An engineering faculty member and a faculty member from a school of Peace Studies have developed this course. The course focuses both on the design and use of drones while focusing on cultivating empathy across disciplinary boundaries
- *Diplomacy and Negotiations in Humanitarian and Environmental Engineering Projects.*
  Two engineering faculty members and a faculty member from the School of Peace Studies are developing this course. The course focuses on teaming skills and the impact of internal team negotiations and negotiations with those impacted by engineering designs.
- *Power and Power Module: Legacies of Apartheid in South Africa*
  Faculty from engineering, sociology, and political science professor are designing course materials through which students will examine the intersection of the engineering meaning of power (energy per time) and the power resulting from privilege (social injustice).

Three additional courses have been influenced by the RED grant. These include:

- A *User-Centered Design* is a required course for engineering majors, which introduces students to strategies for developing designs that emphasize how users interact with the final product. The course has been determined to achieve the outcomes of the Diversity, Inclusion, and Social Justice (DISJ) requirement for the University core curriculum. To our knowledge, this is the only required engineering class that is also approved for satisfying a campus-wide, core curriculum diversity requirement. The new outcomes include that by the end of the course, the students will:
  - Have critically reflected on, compared, contrasted, and articulated their own unearned advantage (privilege) and disadvantage in relation to their immersion experience with users.
  - Be able to use qualitative research methodologies (e.g., interviews, observation, and immersion) to engage users and explore users' experiences related to intersectionality of issues such as race, ethnicity, gender, age, physical ability, immigration status, literacy, and language.
  - Have described how users' experiences and the engineering design process may be influenced by societal norms and structures that create disparities of privilege and oppression around intersectionality.
  As part of the final project, all students were required to engage with community members through an immersion experience.
- An *Engineering and Social Justice* course has been offered and a revised version is under development. This course has been taught twice as an intensive, three-week intersession course.
- A *Humanitarian Engineering* course was taught based on materials from classes at other schools including the Colorado School of Mines.

Looking forward, modules are currently being developed for an engineering materials course, a statics course, and a circuit's course.

Many, if not most, engineering faculty members may not have the ability to develop and contextualize engineering curricula with social justice, humanitarian practice, peace, and sustainability or to effectively infuse professional skills into the curriculum. Several approaches have been used to attempt to bridge this gap. The approaches include pairing engineering faculty with faculty from other disciplines such as the social sciences, liberal arts, and peace studies to develop content and to learn form each other. In addition, a variety of *"Faculty Empowerment Workshops"* were offered. *Faculty Empowerment* workshops are events dedicated to providing the faculty with preparation needed to effectively teach professional skills such as teamwork, communication, social impact, and ethics. These also include discussions of effective pedagogies (e.g. active learning, or project-based learning) and innovative approaches such as incorporating everyday examples. Three *Faculty Empowerment Workshops* were held during the past year, which include:

- *Teaching Student Teams*
  This workshop, from Matthew Ohland at Purdue University, was designed to help faculty design, implement, and evaluate positive team-based learning experiences for their classes. The workshop was delivered and focused on the CATME (see www.catme.org) model of teamwork to present proven strategies for forming, teaching, and managing teams for small assignments and large class projects. This workshop helped faculty develop the capacity to help form more effective student teams, and assess their performance. This capability will help develop the "teaming" professional skills desired by industry.
- *Leading Effective Discussions in Engineering Classes*
  This workshop was developed for engineering faculty by our university's *Center for Teaching and Learning* to address the faculty-identified need to learn how to sustain high-quality classroom discussions about non-technical aspects of engineering practice. This workshop offered opportunities to engage different facilitation styles using a case study approach. It was the first workshop developed specifically for engineering faculty by the CEE demonstrating a productive collaboration across campus. In this workshop the faculty learned additional tools that they can use to make their classes more effective by breaking away from "chalk-and-talk" lectures. The use of cases as a source for scenarios to be analyzed in engineering classes will also make it easier to introduce topics related to social justice, and humanitarian engineering.
- *Engineering Education for Social Justice*
  This workshop was developed to understand critical issues that must be considered when evaluating the how the learning outcomes for a technical course might be framed in the context of social justice.

A Faculty that embraces a redefined engineering canon

Many of the schools faculty members were skeptical of the need for significant changes to curricula. Recognizing this, another goal of the RED grant was to: *"Create a culture within the school where faculty recognize the need for a revised canon that infuses professional skills and values with disciplinary content to develop changemaking engineers."*

Consequently, a primary approach for achieving change is to use a transformative and emergent change model [1] to develop broader support for the transformation. To address this goal, *"Collaborative Leadership Workshops"* were developed. *Collaborative Leadership* workshops are events designed to help faculty create a shared vision of Changemaking Engineering, and the revised engineering canon. They also explore methods and tools for shared leadership. The events held this year include:

- *The Origins of Changemaking Engineers* Workshop
  This workshop, from Virginia Tech's Matthew Wisnioski, focused on the history of Changemaking Engineering including prior attempts to infuse humanitarian engineering and social justice issues into the engineering curriculum. The purpose was to provide the RED team and faculty with an historical perspective of efforts similar to ours so that we have a better chance of success. The workshop helped faculty to understand the barriers that made previous attempts to infuse engineering with humanitarian principles difficult to maintain.
- *Strategic Planning Sessions*
  The work of the RED team aligns with the University's recently adopted strategic plan that launched six pathways for institutional change including, becoming an *Anchor Institution*, *Practicing Changemaking* and *Care for Our Common Home*. The RED team leveraged this institutional initiative as an opportunity to develop to identify strategic opportunities in the School of Engineering that are consistent with the RED grant. Three strategic planning sessions in the school that emphasized developing a shared meaning of *Changemaking Engineering*. Faculty members performed a SWOT analysis and then identified the most important opportunities that we should pursue under the theme of Changemaking Engineering. The school-wide strategic planning sessions provided an opportunity to identify common goals for the future of SMSE and to relate these goals to the campus strategic plan, and to the RED *Changemaking Engineering* initiative. The school of engineering faculty and staff identified the following critical elements to the development of *Changemaking Engineer through the strategic planning sessions*:

  1. A broad context for how engineering supports the greater good
  2. A holistic approach to engineering practice
  3. Strong technical skills
  4. Effective professional skills
  5. Broad understanding of the impact of engineering decisions
  6. A desire to have an impact on society
  7. Resilience to failure
  8. The ability to change society

  The top priorities for a strategic action plans include:
  1. Develop an *Engineering Exchange* that connects students and faculty with opportunities to work on authentic, community-inspired engineering projects.
  2. Increase cross-campus collaboration.
  3. Increase experiences in the community.
  1. Increase discussions of social justice and sustainability in the curricula.

Partnerships and the industry scholars program

A third goal of the NSF RED grant is: *Establish partnerships with industry, community, and students that value our vision of changemaking engineers.* One of our partnership approaches has been to host the "Engineering, Social Justice and Peace" Conference in January 2018. The Engineering, Social Justice and Peace (ESJP) network comprises an international community of activists, academics, and practitioners dedicated exploring the nexus between engineering, social justice, and peace. Conferences are held annually throughout the world. About 50 people attended the conference. The result helped establish a connection with many others who have similar goals. Additional partnerships have been developed across the university in the School of Peace studies and in the College of Arts and Sciences as a result of the grant.

In 2017 the RED team also worked with industry and community members to socialize the RED grant and to develop engagement activities for the grant. This led the development of programing for students and faculty associated with the RED goals. Besides affirming support for the RED objectives, these engagements have resulted in a new *Industry Scholar* program, which was designed and developed by the industry and community members.

The objective of the program is to infuse students with professional skills and to enhance the capacity of faculty to help teach those skills. The program outcomes include:

(1) Students [and faculty] will be able to describe and discuss expected engineering professional and leadership skills.
(2) Students [and faculty] will demonstrate increased ability in professional and leadership skills.
(3) Students [and faculty] will be able to describe and discuss a variety of engineering related industries and employment types within those industries.
(4) Students [and faculty] will expand their network of industry connections.
(5) Students will have an experience that enhances their resumes and increases their capacity for future employment.
(6) Industry partners will identify potential students that could fit within their organizations and develop a relationship with them before the students reach their junior and senior years of study.
(7) Students will be able to easily transition to internship and employment in junior and senior years.

The first year design resulted in a year-long program that introduced first and second year undergraduate students to professional skills through experiential workshops (things you do not learn in engineering schools) through workshops, industry site visits, and internships coordinated by industry mentors.

In the first cohort, 27 students and six faculty members were selected to participate. Four workshops were conducted along with two industry site visits. Nine of the students also participated in summer internships. Assessment of the first year program showed that the program outcomes were all achieved, with significant growth in areas such as abilities to

describe and discuss expected engineering and leadership skills, ability to interview, self-awareness, and effectiveness at communication. For more information on the program see [2]:

General Engineering: an Incubator of RED

A primary approach for meeting the goals of the RED grant was by building a faculty learning community, seeded within the new general engineering (GE) program, in which faculty development and engagements are supported intentionally and rewarded explicitly. One having developed a strong department where practices that meet these goals is instilled, the practices are intended to influence the other departments resulting in the adoption of new curricula. This approach is based on a skunk-works model, described by Fosfuria and Røndeb, [3] where new development is separated from established and traditional structures. It differs, however, in that the goal is not to develop a new product in isolation, but to develop by attracting others into the community (here a learning community) and growing that community. Much of our early curricular development has been done within a new engineering structure created to support the new GE department. This new department and program allows us to imagine and create curricula that are significantly new and to do so outside of the established school engineering canon.

To develop the new GE department a cluster hire approach was used. The object of the cluster hire was to recruit a cohort of faculty members that value the goals of the RED grant. Previous experience with cluster hiring for an NSF ADVANCE grant at the university resulted in a diverse cohort of faculty members committed to the goals of the cluster hire. In the ADVANCE case, this process centered interdisciplinarity and a commitment to mentoring underrepresented groups in STEM. This RED hire was centered our goals related to social justice, humanitarian engineering, sustainability, and peace. We received about 120 responses to the RED search, of exceptional quality, including internationally renowned leaders in engineering and social justice. We attracted scholars who have started humanitarian engineering programs, and others with a proven track record of working to expand opportunities in engineering to underrepresented groups. We brought seven finalists to campus, and all were very well received. Four new faculty members have been hired in the GE department, all aligned with RED goals. It's clear to us that we would not have had the same type of response without the support of the RED program. For more information on the GE department see [4].

Summary

[[University]] is making progress toward establishing a foundation for a revised engineering canon through the development of courses and modules that focus on professional skills and that contextualize engineering with social justice, humanitarian practice, peace, and sustainability. We are developing a faculty that embraces the redefined engineering canon and the professional spine through faculty empowerment workshops and by hiring faculty with the desire to contribute to the RED goals. We are also establishing partnerships to develop a culture of change within the school and developing professional skills including greater connections between technical knowledge and professional practice through an industry-developed "Industry Scholars Program. Finally, we are using a new "General Engineering" department as an incubator of RED curriculum staffed with cluster hires around the RED proposal themes.

References

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