

# Making Engineering Sociotechnical

Chell A. Roberts and Susan M. Lord  
*Shiley-Marcos School of Engineering*  
*University of San Diego*  
San Diego, CA USA  
croberts@sandiego.edu and slord@sandiego.edu

**Abstract—** Under the National Science Foundation Revolutionizing Engineering Departments (IUSE/PFE: RED) program, we proposed to “Develop Changemaking Engineers” by infusing the socio with the technical into engineering education, and in the process to revitalize the conversation about what engineering is within the academy. In this project, we have developed curriculum that infuses the lenses of social justice, humanitarian practice, and peace into engineering content. We have also developed workshops aimed at broadening the capacity of engineering faculty to teach these topics. We have also created focused cluster hiring to bring new faculty to the school that have the desire and expertise to work in these areas. Finally, we have reached out to other schools and universities to find others who want to engage with us as we try to redefine the engineering canon.

This work-in-progress paper includes reflections on this work from two perspectives: that of a department chair who created a new department as a place to prototype new curricular ideas and that of a dean of engineering that has been working with organizational change. From our two viewpoints, we reflect on:

1. Challenges in understanding the goals of making engineering education more sociotechnical.
2. Having the conversations about what engineering is and what it is not.
3. Changing the culture within the school to value the sociotechnical nature of engineering.

**Keywords—***sociotechnical, engineering canon, new program development, difference makers*

## I. INTRODUCTION

The understanding of what engineering is and is not has changed significantly since the first days of the industrial revolution. The design of devices and systems, such as computers and the internet, has had an impact on our social lives, including how we gather information, how we work, and how we interact. The National Academy of Engineering (NAE) formally recognized that engineering was a social enterprise in the publication of a symposium of the NAE in 1991 [1].

*The title of the symposium, "Engineering as a Social Enterprise," was chosen to imply that engineering functions inseparably from the society of which it is a part. To operate within that reality, we need to comprehend better than we do what requirements and constraints are put on engineers by the rest of society and what role the engineer realistically can or should play in that society. [1, p. 2]*

Under the USA’s National Science Foundation (NSF) Revolutionizing Engineering Departments (IUSE/PFE: RED) program, we proposed to “Develop Changemaking Engineers” by infusing the socio with the technical into engineering education, and in the process to revitalize the conversation about what engineering is within the academy.

In this project, we have developed curriculum (courses and modules) that infuses the lenses of social justice, humanitarian practice, and peace into engineering content [2]. Thus far we have developed seven modules and three courses. We have also developed workshops aimed at broadening the capacity of engineering faculty to teach these topics. A focused cluster hire brought new faculty to the school who have the desire and expertise to work in these areas. Finally, we have reached out to other schools and universities to find others who want to engage with us as we try to redefine the engineering canon.

This work-in-progress paper includes reflections on some of the successes and challenges of this work from two perspectives: that of a department chair who created a new department as a place to prototype new curricular ideas and that of a dean of engineering that has been working with organizational change. From these two viewpoints, we consider our personal experience with:

1. Challenges in understanding the goals of making engineering education more sociotechnical.
2. Having the conversations about what engineering is and what it is not.
3. Changing the culture within the school to value the sociotechnical nature of engineering.

## II. DEAN’S PERSPECTIVE

I have been an academic for more than 30 years, serving as a faculty member, an associate chair, a chair, and associate dean, and as a dean. I have worked at a very large public university with tens of thousands of engineering students and at a smaller private university with less than a thousand engineering students. I am currently the dean. I embraced engineering education, the research, and reports in the area when I became a chair many years ago. I have spent a significant portion of my career since that time focused on improving teaching and learning, since I believe that is what engineering education is about. I believe that all professors who teach, are part of the guild of engineering educators, even if they do not understand the research in the area. Most of my

insights are based on my perception and experience with the input of many other deans of engineering.

*A. Challenges in understanding the goals of making engineering education more sociotechnical*

Who defines what engineering is and what knowledge should be imparted to students? The answer seems to me to be complex, historical, at times ideological, and variable depending on who one talks with. However, I would argue that the engineering faculty hold a significant position in this determination. Certainly, there is significant input from the engineering societies, from the National Academy of Engineering, and the National Science Foundation. Also, the dean and other internal leaders have significant input, both through influence and through structure. However, in my experience, the engineering faculty determine the curriculum, teach the curriculum, have significant input into the creation of promotion and tenure policy, and then vote on the impact and appropriateness of a particular faculty's body of work toward tenure. Most faculty have been educated by other faculty who hold certain values, with the vast majority rooted in a technocentric engineering worldview. These faculty then become part of that body of faculty who have passed the tenure test and who can contribute with voice to what engineering is taught and what is appropriate. This has a big impact on how culture is developed and maintained.

At least 20 years ago I experienced the discussions of the senior faculty who had relegated engineering education research to a subordinate status. This perception has softened somewhat, but a persistent perception of what engineering is seems to be rooted in "rigorous" mathematical demonstrations of engineering analysis and design. This view is important, though perhaps not comprehensive. Many faculty members have pointed to the higher impact factors of journals that focus on mathematical approaches to engineering. The prevailing attitude among some senior engineering education faculty is that faculty who work in engineering education should demonstrate traditional disciplinary depth beyond their PhD work, and then focus secondarily on education. This approach is safer and can mute criticism. I believe that this view, in part, comes from a perception that engineering education research is easier (or perceived as easier and less rigorous) than what other traditional engineering faculty do. A good deal of engineering education research uses research methods that reach into the social sciences. The vast majority of engineering faculty have not been educated in these research methodologies. I had one faculty member who was comparing his work to engineering education faculty, tell me that he also used rubrics, but that they could not do what he does.

For many years I have heard talks and the expressions of other deans who echo the words: "Engineering is Sociotechnical." I believe now, that when those words are put into a common engineering faculty framework, where engineers end up working on solutions and designs that have social context, faculty readily agree that engineering is sociotechnical. Faculty are pleased when their students develop designs that help the society and people. However, they do not embrace the idea that there are educational components that scaffold students to be able to design solutions that are appropriate for a given

population. Those components are also rooted in the social sciences, which are foreign to most faculty. Some faculty tell me we should let the social scientist teach our students about socio relevant issues and let them use that knowledge appropriately, while the engineering faculty stick to "real" engineering. A problem with that view, is that students need to learn in context. They cannot evaluate the social consequence of their college work without guidance of that work. Student have a difficult time transferring knowledge from one domain to another – actually, so do faculty.

I believe that the last revolution in engineering education was to bring a disciplined approach to engineering education. This has been evidenced through the PhD programs that have emerged in the area and an increase in hiring faculty with an engineering education research background. Much of that disciplined approach included embedding the research methods from other disciplines such as the social sciences. Thus, the research in engineering education developed the foundation to make engineering education sociotechnical. I further believe that we are now emerging on a next revolution in engineering education, making engineering education sociotechnical, meaning that there will be attempts to embed sociotechnical thinking and analysis into the curriculum.

*B. Having the conversations about what engineering is and what it is not.*

It occurs to me that most of our current engineering faculty have developed professional values that favor complex technical work. I have experienced disputes between faculty from different engineering disciplines as to which discipline is the most rigorous and correspondingly the "best". Some of the brightest engineering faculty I have encountered become rigid and defensive when they are put in positions that require evaluations of other faculty who have different values and approach engineering differently than they do. Years ago, I naively believed that our PhD educated faculty, who are certainly experienced with data and evidence, would be able to accommodate difference, and value the recommendations of the numerous engineering education reports. Because of this belief, I brought out some of those reports and invited prestigious national leaders to speak to my faculty. The reaction was surprising. Some of the recommendation simply were ignored. Some marginalized, and a very few embraced. I now believe that the national reports did not speak to something that the faculty understood. Their values framework was unable to accommodate the difference without requiring an internal change to individual professional values. It is a hard thing to ask faculty to reflect on their long held, institutionally developed and validated values. Some see the acceptance or even the consideration of alternative values as devaluing what they have done for an entire career, and as many have said: "what I do has worked very well, I have educated hundreds or thousands of students who are successful".

I recall one particular promotion and tenure meeting where several faculty members scrutinized the work of a faculty doing research on sociotechnical issues. The faculty had numerous publications and grants that used frameworks and

methodologies unfamiliar to those that performed research and teaching in strictly technocentric ways. There was conversation around the impact factors of the journals, which tend to be lower in engineering education. Despite discussion of the relative disciplinary nature of impact factors, opinions did not change. There were recommendations that suggested telling the faculty to change research focus and to teach more courses that were technical.

### *C. Changing the culture within the school to value the sociotechnical nature of engineering.*

When we first embarked on the Changemaking Engineering grant, we believed that faculty simply did not have the skillsets to teach sociotechnical content. Thus, we offered several faculty capacity building workshops and brought in numerous speakers to show the faculty how this might be accomplished. Most faculty would not attend the workshops. I noted that it was the same small percentage of the faculty that had already embraced the concepts that attended most of the workshops. There were a very few traditional faculty that engaged, and for whom there was some change.

As a dean, I have focused on hiring people who care about the sociotechnical aspect of engineering. Many of them do research in the area, others are simply open to multiple perspectives and values. However, early career faculty will be more tenuous in voicing opinions as they look to tenure and try to conform to academic norms. One can build culture through who they hire, if who they hire believe they can make it in the academic environment. A new PhD faculty may not understand the complexity of academic socialization.

There are some senior faculty who have told me that they need to stand up against changes in engineering curriculum that in their minds dumb down the curriculum. They view their roles as “protectors of engineering and the school.” Some of the early career faculty have been told by a promotion and tenure committee chair, that the topic of their research would jeopardize their careers. I had a visit from one of these early career faculty who asked if they fit in the school and if they should consider going elsewhere.

I believe that change is difficult and takes patience and years of work. Some people may change their views, many will not. We should value differences of opinion, academic discussion, and the wisdom of those who have experience. Navigating the value of discourse and making decisions about structure, hiring, and who is empowered is challenging. Some of the dissention is political. Who is empowered and who is not makes a difference. Long term change means that there must be sufficient internal momentum and structure to outlast a particular leader or dean or chair. The value needs to become a value of the school if the change is to persist.

### III. CHAIR’S PERSPECTIVE

I have been an academic for more than 20 years serving as a faculty member rising through the ranks to professor and as chair. I have an interdisciplinary background in electrical engineering and materials science and engineering. My

graduate and undergraduate education was at Research 1 universities. I have taught engineering at smaller primarily undergraduate institutions within a liberal arts context. My research is in engineering education, which is closely aligned with the goals of this RED project. I am a passionate educator who facilitates an annual workshop for other engineering faculty about effective teaching. I have played several roles in this “revolution”: champion, entrepreneur, faculty member, and researcher. I started as the chair of Electrical Engineering and then moved to being the chair of the new Integrated Engineering department. My perspective is shaped by the marginalization I have experienced as a woman in engineering. This has shaped my deep desire for revolutionizing engineering to be more inclusive.

### *A. Challenges in understanding the goals of making engineering education more sociotechnical*

Our RED grant is entitled “Developing Changemaking Engineers”. We chose this title to tie in the efforts on our campus related to the Ashoka Foundation which has designed our campus as a Changemaker campus. When the proposal was submitted, our RED project team included the Dean of our School of Engineering as principal investigator (PI) with the rest of the team including the Associate Dean, the Chairs of Mechanical, Electrical, and Industrial and Systems Engineering, and a professor from Sociology as the Social Scientist/Change Expert. I played a dual role as Chair of Electrical Engineering and the Engineering Education Research expert.

The project team had different understandings of what “changemaking engineers” meant when we wrote the proposal and when we started implementing it. Over several years, we came to more of a common understanding of changemaking involving seeing engineering as sociotechnical. This actually involves two aspects: helping others see engineering as sociotechnical and exploring why it is not i.e. combating the sociotechnical divide. Our focus has been more on the former.

### *B. Having the conversations about what engineering is and what it is not.*

For me, this RED project and my new department of Integrated Engineering, have involved re-envisioning what counts as engineering and thus what the priorities are for my classroom. One way I think about it now is that as an engineering professor, I feel like I am not doing my job if I don’t help students learn to analyze data. This is still true. I want to move to a place where engineering professors feel like they are not doing their job if they do not help their students appreciate the larger context of engineering. So, we should discuss economics, social impact, environmental impact in our engineering classes, not just if we have time, but as an integral part of helping students to become effective engineers.

I have been a champion of this work. I have tried to help others learn more about engineering education research so that they can publish their results of doing such exploration. I have advocated for doing this work and supported my colleagues who are doing it. As such, I have also been what has felt like “in the

line of fire” from other engineering faculty outside my department particularly in faculty meetings where curricular matters are discussed and voted on. Much of the conversation has felt like personal attacks on me and my Integrated Engineering colleagues. There have been criticisms of the “rigor” [3] and usefulness of our courses and degree program.

### *C. Changing the culture within the school to value the sociotechnical nature of engineering.*

This view of engineering as sociotechnical is in keeping with the mission of our university and our school of engineering. Our engineering students receive a BS/BA as they take the same core curriculum as all other undergraduates on campus. For me, a modern liberal arts education requires consideration of topics within and outside of one’s major. For some faculty at our institution, these courses outside engineering are seen as valuable but separate. Students are expected to do the integration, tying together concepts from their philosophy class with their circuits’ class, for example. For me, part of RED and Integrated Engineering is building on this foundation of valuing the liberal arts but going one step further and helping students to integrate these concepts such as consideration of conflict minerals in a circuits class [4, 5]. This is difficult work and faculty can be helpful to students here. However, it is challenging and many faculty do not feel comfortable leading discussions or exploring topics outside of technical calculations. Concerns range from lack of expertise to fear to a belief that this is “not my job”.

These are significant and real challenges and may require a change in one’s vision of what is engineering and thus one’s identity as an engineer. This is likely to lead to resistance. There are reasons why the sociotechnical divide exists and the status quo is invested in keeping this. For example, it is not a coincidence that engineering continues to suffer from a lack of participation of women and people of color. Rather, the system is functioning as intended including a lack of diversity [6]. There

are challenges in having faculty from underrepresented groups emphasizing sociotechnical context of engineering. As a chair and a woman, I am acutely aware of this tension. I think revolutionary change must have some resistance and if you can see your way clear to the final destination at the beginning, it is probably not a revolution.

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