The feminist engineering classroom: a vision for future educational innovations

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Abstract

In the quest for the gender equalization of the engineering profession, a variety of strategies are being developed and used in daily engineering education practice. Colleges and universities are recruiting girls and women in increasing numbers into the so-called "engineering pipeline" by using camps, special classes, printed and internet-based advertising, and/or "girl-power" media programming to make engineering's image more appealing – for example, as fun, socially useful, and multidisciplinary. Concurrently, engineering instructors and faculty are redesigning engineering education using different classroom techniques more congruent with current managerial trends found in industry. These lean towards a focus on group work and interdisciplinarity, which have the added advantage through their political and material reputation as being purportedly more "women-friendly" than traditional methods. These different interventions are crucial in the nation-wide quest to have men and women more proportionately represented in engineering. Arguably, the last bastion is to address the *content* of engineering courses, which has changed only superficially. This is despite considerable theoretical and practical critiques of science and engineering practice in academia that have been made by feminist researchers and educators. This paper introduces the field of feminist science studies to engineering educators, discusses various explicitly feminist approaches to changing content in engineering, and challenges engineering educators to consider what a "feminist engineering classroom" might consist of with respect to content.

Introduction

University of Wisconsin-Madison professor Caitilyn Allen is an unusual hybrid – jointly appointed in plant pathology and women's studies, she blends these two apparently disparate fields through her research and teaching in each. In a recent article,[1] she writes about being an "academic dual-citizen," and lists several questions of interest that she uses to describe her work in feminist science studies to her scientific colleagues:

> "It is … quite unusual for active research scientists to devote professional energy to the issues that appear central to feminist science studies. These issues might include such questions as: How do gender-related expectations bias scientific research on seemingly gender-neutral subjects like biochemistry and agriculture? What difference might it

make if scientists as a population were more diverse? Is any fact objectively knowable?" (p. 25)

Allen's case is an unusual one in part because working in both fields requires a fluency in two difficult and jargon-laden languages – that of her science, and of feminist science studies. However, this fluency is worth attaining, as feminist critiques of science are crucial to improving scientific theory and practice. In particular, feminist science studies offer new theoretical frameworks to analyze women's longtime underrepresentation[2,3] in engineering and the physical and biological sciences in the United States.[4] While substantial advances have been made overall, progress has begun to stagnate over the last decade. A new approach, involving an existing body of literature that engineering education has heretofore overlooked, might provide a more nuanced understanding of this disproportionality, and might allow for more effective solutions. In this paper, I argue that we have yet to understand what effect the gendered nature of the *content* of engineering and our engineering courses has on men's overrepresentation in engineering, and I propose that we use work done on gender in feminist science studies to address this omission.

Background

As portrayed in the publications and conferences of ASEE (as elsewhere) the majority of gender-proportionality efforts employ one of two general strategies. The first has been described (usually by critics) as the "add-women-and-stir" method. Using the metaphor of plugging a leaky "pipeline,"[5] these programs and models concentrate on directly encouraging more women to enter science, technology, engineering and math (STEM) fields through camps, special classes, printed and internet-based advertising, and/or "girl power" media programming. The second strategy addresses the "chilly climate" issues recently highlighted by the landmark MIT study.[6] When applied to undergraduate education, chilly climate models encourage instructors to redesign engineering education using different classroom techniques more congruent with current managerial trends found in industry. These lean towards a focus on group work and interdisciplinarity, which have the added advantages through their political and material reputation as being purportedly more "women-friendly" than traditional methods. The new NSF publication "New Formulas for America's Workforce: Girls in Science and Engineering"[7] provides a good summary of programs stemming from these models.

In recent years, many of the papers presented at the national ASEE conferences in the Women in Engineering Division have focused on innovative and often effective programs stemming from these two philosophical standpoints. Indeed, the proportion of women to men recruited and retained in most engineering disciplines at most schools has improved dramatically over the last fifteen years. The movement has even progressed as far as the founding of the first engineering program at a women's college – Smith College, in Northampton MA – a feat that was almost unthinkable ten years ago, and which still raises skeptical eyebrows amongst some engineering administrators (both women and men). These are considerable advances in women's education – their support and growth need to be sustained and encouraged. However, there are other ways to think about gender in engineering beyond the simple metric of women's numerical participation – the engineering educational community has largely overlooked these, I believe to its severe detriment.

Until late in the 20th century, most work on gender was of the sex-differences ilk – analyzing the psychological, physical, mental, or other differences between the dichotomized categories of women and men.[8,9] In the science and engineering education context of this paper, many researchers have been absorbed by questions of differential aptitude for spatial reasoning, mathematical ability, pedagogical temperament, etc., between genders (operationalized as "women" and "men") to explain men's overrepresentation in these fields.[10-14] These studies have entirely failed to consider the social construction of these categories, assuming that they were obviously "natural," characterizable, and distinct. Subsequent feminist research has challenged this categorization, and has called for a more sophisticated and accurate definition of gender.

In an influential paper published in a mainstream history journal in 1986, and which has had widespread impact on disciplines throughout the humanities and social sciences, Joan Scott argues[8] that the definition of gender must take into consideration the fact that it is "a primary way of signifying relationships of power" (p. 1067) in Western society. She writes that gender functions as a social force through culturally important symbols, through stories and metaphors which make use of those symbols to explain aspects of society, through the ties of kinship developed through and influenced by our labour market, educational system, and polity, and through "real" people's own subjective identities. This conceptualization is considerably different from how gender is analyzed in most engineering journals. Other work on gender in the humanities and social sciences has problematized the dichotomy of "male" and "female," arguing that gender identities are flexible within historical and social contexts, and that they are not even characteristics of individuals but are embodied in roles (sometimes multiple and conflicting roles) actively performed using socially relevant – and therefore contextually dependent – symbols.[9, 15-19]

An Introduction to Feminist Science Studies

The growing field of feminist science studies is one area within STEM contexts where gender *is* analyzed in the manner Scott advocates. Maralee Mayberry, Banu Subramaniam and Lisa Weasel define[20] the field as incorporating "[a] body of work that applies feminist analyses to scientific ideas and practices [… in order] to explore the relationship between feminism and science […] the intersections between race, class, gender, and science and technology, […and the] implications of 'situated knowledges' (knowledge seen as a social activity embedded in a certain culture and worldview)." (p. 8) This definition may seem somewhat jargon-laden to engineers (what are 'situated knowledges' what does race or class have to do with gender, and how are these relevant to real science?) and is perhaps not accessible to many unfamiliar with women's studies and feminist literature. While feminist critiques of objectivity, and the struggles to theorize concepts like voice, authority, identity, ways of knowing and positionality have influenced work in the social sciences, humanities, and education,[21-26] the physical and biological sciences and engineering have remained largely unaware and poorly informed by these advances. However, we in the field of engineering education, especially those of us concerned with making engineering a more equitable and socially responsible environment for all people, cannot afford to ignore the theoretical advances made in the humanities, such as those on gender, simply because they were not initially generated in engineering.

It is not my intention for this paper to summarize all feminist science theory since the 1960s or earlier; however, a brief mention of several additional key arguments relevant to the field is necessary to progress with this discussion. At the heart of many feminist critiques of science is a concern about who participates in the development, process, production, and dissemination of science and engineering. (While “science” is the term most often used to describe the field, scholars certainly also study engineering and the engineering science practiced in academia and industry.) Analyzing the context and practice of science and engineering has resulted in intensely interdisciplinary study, both by feminists and others. Incorporating theoretical frameworks drawn from such sociological concepts as “the structure of occupations, the workings of institutions, the legitimization of erroneous belief, the class structure of science, the sociology of knowledge, or the microstructure of laboratory life”[28] and from histories “focused on intellectual or social history, formal and informal institutions, economic history, or the history of individuals”[28] to philosophy and literary criticism, what is often called “science and technology studies” is growing in reach and depth, and considers the topic of gender in science from many more angles than simply women's underrepresentation.

Feminist science scholars question who benefits from how science is practiced, how scientists produce theory about the natural/cultural/political/social world(s), how scientists determine what is worthy of study and what is not, and who does not benefit from these investigations. Simultaneously, they are concerned with what remains “unsaid” in science: along with many other scholars, Harding[28, 29] has written extensively about the androcentric bias in biology and the social sciences, as has Evelyn Fox Keller,[30] who has criticized science's claims to objectivity and analyzed the effect of “gender ideology” (p. 61) on how science is done. Other scholars have analyzed other aspects of science: for example, Nancy Stepan[32] and Anne Fausto-Sterling[33] have written about the gendered use of analogies in the historical scientific literature to describe, for example, the “natural” elevated status of European men on the evolutionary scale compared to European women and people of colour. While mainstream scientists no longer subscribe to such extreme views, echoes of these practices remain in how sexuality[34] and race[35] are studied, and androcentric metaphors continue to be used throughout the sciences, particularly in biology.[36-38]

Feminist scientists and others have done a great deal of work in the biological sciences, and there is also a growing body of research on engineering and technology. Through a history of the development of technology and engineering, Ruth Oldenziel[39,40] argues that technology itself became gendered through social disciplining of masculinity and femininity, resulting in the gendering of engineering; Judy Wajcman[41] does similarly in the sociology of science, looking specifically at the gendering of technologies of labour and production, domestic technologies, reproductive technologies, and the built environment. Sherry Turkle[42] writes about how online communities and internet worlds allow people to play with and problematize their own gendered identities – users' virtual identities are perhaps more flexible and contradictory than those of “real life,” but, Turkle argues, are no less important or “real” for being virtual.

This description of feminist science studies is, of course, very reductive and simplified – it is always difficult to summarize a vibrant and growing field in a few paragraphs. Let me then move on to how I believe feminist science studies are particularly relevant to engineering and engineering education, namely, for scrutinizing what “counts” as engineering content and why.

The Connection to Engineering

I have argued elsewhere[43] that what now constitutes the content of engineering was strongly defined by historical processes, which were themselves acutely influenced by gender. We can see this particularly in the story of the development of home economics as a discipline by Ellen Swallow Richards, the first woman graduate from MIT, a professor of "sanitation chemistry" at MIT, and the founder of the home economics movement.[44, 45] Through various political maneuverings (such as the 1917 Smith-Hughes Act) home economics came to embody women's general education and "life's work"[45] rather than a scientific professional field, even though many of the actual tasks ascribed to home economics could easily have been considered "science" or "engineering" tasks had they been in a different context. (In fact, Richards strongly lobbied to call home economics "domestic science" or "euthenics" to highlight the scientific nature of the developing field.[44]) For example, nutrition can be characterized a combination of chemistry, biology, and food engineering except when in the context of feeding a family. Sanitation engineering is now its own discipline, but in the home it is morphed into basic hygiene and cleanliness. The characteristics of "hygiene" were adopted by medicine and biomedical engineering, except in the context of women's health and menstruation. In fact, women were effectively "designed out" of engineering and engineering education through the *gendered* sorting and organization of different tasks and topics between socially-defined academic disciplines. Masculinized topics became engineering; feminized ones became home economics.

If, as suggested by this work, we accept that the content of engineering disciplines is not somehow inherently "natural," that is, that engineering and engineering science does not "spring from the earth" already earmarked as mechanical engineering or chemical engineering, we must begin to acknowledge that *social processes*, embodied by people acting in academia and elsewhere, formed the boundaries of what "counts" as engineering and what does not. We might extend this thought then to recognize that, until recently in the history of engineering, the majority of people who did this boundary-drawing were men – specifically white, Western, economically privileged men. The interests, concerns and skills of women from their own lived experiences, perspectives, and knowledge were almost never considered. Our final step, then, towards linking feminist science studies to the need to reexamine our engineering course content has been articulated by many, including Harding[28] who writes that:

> "…[w]omen need sciences and technologies that are *for* women and that are for women in *every class, race and culture.* Feminists (male and female) want to close the gender gap in scientific and technological literacy, to invent modes of thought and learn the existing techniques and skills that will enable women to get more control over the conditions of their lives... How can women manage their lives in the context of science and technologies designed and directed by powerful institutions that appear to have few interests in creating social relations beneficial to anyone but those in the dominant groups?" (p. 5-6)

This may be a sobering thought for many of us who are already experts at what currently counts as engineering. We most likely became engineers because we *liked* what was already considered engineering. The prospect that our subject of interest, which we may have studied much of our adult lives, which we have been questioned and challenged on through our undergraduate, graduate and professional careers, and which has taken up so much of our time, money, energy, and other personal resources, is potentially *damaging* to the social position of women in the world can be a shock. At least, it was for me, at the beginning of my studies in feminist theories of science. After all, I had been learning that the ultimate aim of my work in engineering was to stay objective in my relationship to my subject of study (itself obviously and undeniably worthy of study, or so I thought).

After an initial period of considerable disillusionment, I found the work of scholars, including scientists, who argued that, even though it is not, *and should not be*, entirely objective and rational, the art and practice of science is worth pursuing, participating in, and improving.[29, 46] While I do not expect this to generate a collective sigh of relief from the scientific world, I found this revelation personally sustaining and even galvanizing – what, then, *should* science and engineering look like? How would our vision for the future of engineering change if we took into consideration the criticisms of how science and engineering are practiced, for the benefit of whom, and using what as subject matter? This, then, is the culmination of my argument – to contribute to the monumental task of redesigning engineering and engineering science to be more gender-neutral at *multiple* levels, we need to begin discussing how the content of our classrooms must change.

Recommendation: Redesigning Engineering Content in Classrooms

While the most worthwhile method (and likely most congruent method with feminist practice) for initiating and developing this redesign is through conversations and discussions with other committed instructors, I will include here a few ideas to prime the pedagogical pump. Bonnie Shulman argues[47] that mathematics, and the language of mathematics in particular, is considerably more influenced by social culture than its reputation suggests – she provides examples showing how "[q]uantification, comparison, and measurement are in themselves cultural activities, whose assumed values are not universally shared" (p. 414). She gives a series of wonderful ideas for improving the content of math classes by changing the purpose of math questions. Of math educators, she asks:

> "that we encourage our students to look for hidden assumptions and make them explicit…[w]e must teach them to *expect* a standpoint in any scientific statement and include it as part of their observations…[i]n mathematics, we should include more open-ended problems that require one to make assumptions in order to solve them. In standard word problems, we can append questions that ask students to list what assumptions have been made. Finally, we need to emphasize that there are many valid alternative approaches to the same problem, and even more important, there is often more than one single correct solution. In fact, why must problems always be *solved* and made to give up their secrets? What if we also gave open-ended problems that invite students to imagine more of the story, in order to understand the situation? […] We owe it to our students … to provide them with experiences of the personal, intuitive, creative (and culturally dependent) process of *doing* mathematics, rather than merely reading the codified axiomatic presentation that appears in most textbooks." (p. 416-17)

Through the recognition of mathematics as a culturally influenced discipline, the structure of math problems and course content is thrown up for reevaluation. What image of mathematics is being portrayed when classes are taught around solving distinct problems for a single solution? When the assumptions for certain processes are excluded, how does the scope of knowledge (through research and practice) become falsified?

Other ideas for changing the content of our classes focus on making the process of doing science and engineering explicit. For undergraduates preparing to enter industrial jobs, questions about the development of technologies and their social influences can be raised:

- Who "discovered" a given technology first? What was their social situation in life? What resources did they have at their disposal to help them in their "discovery?"
- What was the historical and social context surrounding this work?
- Where have the benefits of this "discovery" been seen?
- Who has not benefited from it, and why not?

For graduate students, the process of research is worthy of discussion:

- Who pays for research and why?
- How are research questions influenced by the need to secure funding to pay for the investigation?
- What questions do not get asked because those influenced or affected by them cannot pay?

With respect to the current content of our engineering classes, we could ask ourselves:

- Why have we selected these topics to "cover" and discuss? Is it because they have been traditionally included, and if so, by whom, for whom, and for what purpose?
- How has the field changed?
- What are now the hot topics in our field, and why?
- What is important for our students to leave their university experience knowing, and why?

In this spate of questions that I am suggesting for our own and our students' reflection, there is no mention of gender. However, Scott's[8] definition of gender flows through each one, as the study of gender is fundamentally organized around studying relationships of power. Whether we teach safety engineering or fluid mechanics, materials engineering or nanotech research, bridge building or polymer modeling, the content we choose to represent our fields is influenced by social context(s), which themselves are strongly influenced by gendered relationships of power. To make our classrooms truly gender-sensitive, the content cannot remain sacrosanct. We must take up the challenge issued by feminist science scholars to develop an engineering that considers gender a critical yet thoughtful category of analysis, both in our research and teaching.

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