AC 2007-1871: THE INCREDIBLE SHRINKING JOB DESCRIPTION: TRENDS AND CONSEQUENCES OF AN INCREASINGLY TECHNICAL ENGINEERING PROFESSION

Erin Cech, University of California-San Diego

Erin A. Cech received bachelors degrees in Electrical Engineering and Sociology from Montana State University and is currently working towards her doctorate in Sociology at UC San Diego. She is engaged in research on gender and cultural issues in engineering, social stratification, and the intersection of technological and societal ethics.

Kara Boettcher, Montana State University

Kara M. Boettcher is a 2002 Chemical Engineering graduate of Montana State University. She spent three years working as a process engineer for Chevron Corp in Richmond, California and Salt Lake City, Utah. Currently Kara is taking post-baccalaureate classes at MSU to prepare for graduate school.

Heidi Sherick, Montana State University

Heidi M. Sherick, M.Ed., is Assistant Dean for Undergraduate Programs and Diversity in the College of Engineering at Montana State University. She is in charge of efforts to increase diversity in the College of Engineering by recruiting, advising and supporting minorities. She is the Director of EMPower and the Project Director of the DOC program. She has over 5 years of experience in teaching middle school science.

The Incredible Shrinking Job Description: Trends and Consequences of an Increasingly Technical Engineering Profession

Abstract: ASEE promotes the importance of graduating engineers who possess a host of non-technical skills to complement their technical competencies. As this year of dialog draws to a close, the authors are interested in the extent to which such well-roundedness is reflected in the actual work that engages engineering graduates. Using quantitative data from the 1993, 1997 and 2003 National Survey of College Graduates, this paper analyses the changes in work characteristics of jobs that employ graduates of U.S. engineering programs. Contrary to expectations, the authors find that engineering work has become more *narrowly technical* over the last decade. While some may celebrate this trend as evidence of an increased "purity" in engineering work, the authors argue that if this trend continues, serious negative consequences could ensue for engineering education, industry, and the social conception of engineering.

Introduction

The American Society for Engineering Education is committed to reforming engineering education to give students the skills necessary to excel in an increasingly complex occupational world. It promotes the importance of graduating well-rounded engineers who, in addition to their technical competence, have refined communication skills, political savvy, and deep-seated commitments to ethical practice. The visibility and positive reception of the National Academy of Engineering's *The Engineer of 2020: Visions of a New Century*[1] attests to the increasing importance of this commitment. The purpose of this article is to examine the extent to which such well-roundedness is reflected in the actual work that engages graduates of U.S. engineering programs.

In undertaking this study, the authors expected to find evidence of graduates applying their problem-solving skills to non-technical arenas such as policy work, public service, or legislation. This hypothesis was introduced by *The Engineer of 2020,* and serves as an axiom within the ASEE community. The authors ventured beyond *The Engineer of 2020*'s "suite of recommendations" to conduct a more quantitatively rigorous analysis of engineering work over the last decade. Contrary to expectations, the work that engages engineering graduates does not reflect this well-roundedness and is instead becoming more *narrowly technical*. While staunch traditionalists may celebrate such a narrowing trend as evidence of an increased "purity" in engineering work, the authors argue that serious negative consequences could arise if this trend continues.

This paper will describe the narrowing trend in engineering through a quantitative analysis of a decade of national survey data, and critique the trend from the vantage points of education, industry, and society. Analysis of the causes of this trend is beyond the scope of this paper. As a result of this study, the authors provide provocative insights into current engineering trends in the hope that it will fuel reform in engineering education.

Quantitative Analysis of the Engineering Profession: 1993-2003

Engineering has a vibrant history--from its birth out of the craft tradition through its development into a prominent and respected profession. For over a century engineers have enjoyed prosperity and respect as professionals, and as individuals. Engineers' social status hinges on their ability to utilize expert knowledge to solve problems deemed important by a broader public[2,3]. While this basic premise remains unchanged, the problems to be solved and the list of potential solutions have changed dramatically over the years. Engineering education reform seeks to widen engineers' education so that they may solve a broader range of problems with more innovative and socially responsible solutions. Any analysis of the changes in engineering work over the last decade must therefore pivot around a discussion of the types of problems and solutions that exist within the field of "engineering".

Though one cannot know how all engineering graduates apply their degrees, it is possible to infer from occupational data the types of problems and solutions they encounter. This study examines the changes between 1993 and 2003 in work characteristics of the *jobs that employ* graduates of U.S. engineering programs, looking specifically for a reflection of the well-roundedness of engineering education in their employment.

Methodology

This study utilized the 1993, 1997 and 2003 phases of the National Science Foundation's National Survey of College Graduates (NSCG). The sub-sample selected for this study consisted of NSCG respondents who indicated that their highest degree was in an engineering field. By selecting a sample based on education, rather than occupation, the authors analyzed the full spectrum of jobs that employ engineering graduates. Furthermore, this study was not a longitudinal analysis of how the jobs of a particular cohort of engineers are changing, but about how, as a whole, the job descriptions of engineers are slowly shifting. The sample sizes for the 1993, 1997 and 2003 surveys were 25,206, 26,429, and 17,091 respectively. Though they differ in size, all three samples are large enough to ensure adequate representation, to dispel concerns over statistical significance, and to make definitive statements about the work of engineers over the decade that passed between the two surveys.

The authors carefully disaggregated respondents by their levels of educational attainment and gender in this analysis to uncover any unusual trends. These subcategories are highlighted where appropriate. The next subsections will present the statistical data and the three dimensions of the narrowing trend revealed by this study.

A Narrowing Trend on Three Dimensions

In order to attain the best possible understanding of the work that engages engineering graduates, the authors approached this study from three different dimensions: respondents' job titles, the daily tasks that make up their jobs, and the proximity of their work to their engineering degrees. A narrowing trend exists on all three dimensions.

The first of these dimensions, job titles, is the most obvious proxy for the type of work that engages engineers. Categorizing each job as "technical" or "non-technical," the authors found the percentage of respondents employed in non-technical jobs in 1993, 1997 and 2003. As Table 1 illustrates, the percentage of engineering graduates employed in non-technical jobs decreased by 8.7% between 1993 and 2003. This means fewer engineering graduates in 2003 used their expert problem-solving skills to solve problems in non-technical fields than ten years prior. The potential consequences of this finding are discussed in the next section.

This trend is exasperated for women engineering graduates whose presence in non-technical jobs decreased by 13.5%. Like all quantitative data, this information could be read in a number of ways. One interpretation is that the retention of women engineers in technical careers increased over the last decade—a success for diversity in those fields. However, changes across fields say nothing about where women and men are located in the vertical hierarchies of their organizations and thus cannot be used to make any claims about increased gender inequality over the last decade. The retention of women engineering graduates in technical fields remains less then the retention of men, maintaining the under-representation of women in the technical fields. More importantly, the narrowing trend is evident even for women engineers, who have historically taken up non-technical careers at a higher rate than men.

Table 1: Percent of Respondents Employed in Non-Technical Jobs

	1993	1997	2003
Total Population of Engineering Graduates	42.0%	40.1%	33.3%
Women only Engineering Graduates	48.3%	42.1%	34.8%
Men only Engineering Graduates	41.4%	35.6%	32.9%

While job titles are the most obvious proxy for understanding work activities, there exists a great deal of variability in the types of day-to-day work that engages different people within the same job title. Therefore, the second dimension of interest was engineering graduates' primary job responsibilities. Respondents chose between a list of thirteen responsibilities and were asked to choose the task that comprised the majority of their day-to-day work activities. The responsibilities were categorized as technical (basic research, applied research, development of knowledge, design, computer applications, production, and quality management) and non-technical (accounting, employee relations, management, professional services, sales/marketing, and teaching) and tallied for the three surveys (see Table 2). For the total sample of engineering graduates, and for each sub-sample, the percent of people with strictly-technical primary job responsibilities increased over the decade. This trend was particularly visible for respondents with an B.S. or a M.S. in engineering and was again exaggerated for women. This finding, paired with the information on job title categories, suggests that the day-to-day work engineering graduates perform is now more technical than in the previous decade.

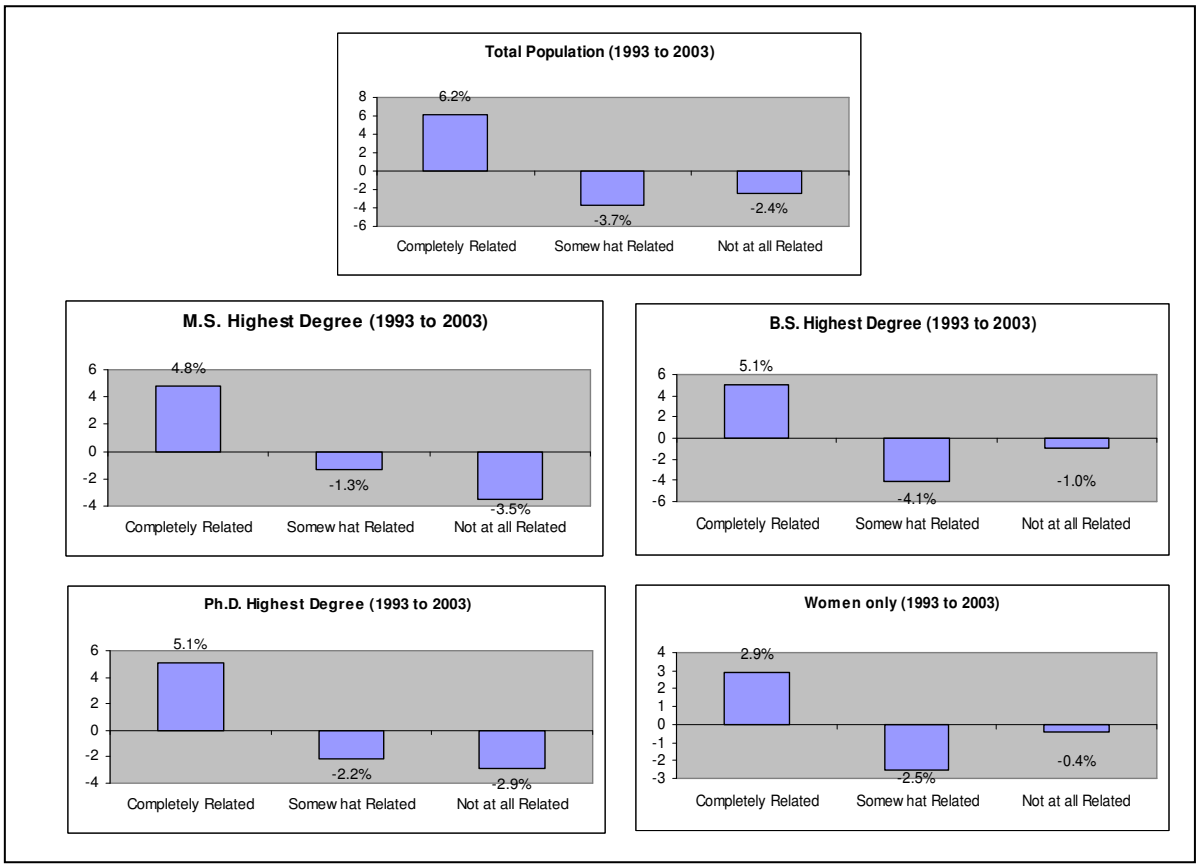
Table 2: Respondents with Strictly-Technical Job Responsibilities

	1993	1997	2003
Total Population	57.0%	61.3%	63.5%
B.S. Highest Degree	54.2%	56.7%	60.3%
M.S Highest Degree	60.3%	67.7%	68.8%
Ph.D. Highest Degree	66.8%	66.9%	70.6%
Women only	51.9%	59.2%	61.0%
Men only	57.4%	62.2%	63.9%

The final dimension explored in this analysis was how closely engineer graduates' occupations matched their engineering degrees. If engineering work is narrowing, the work that engineering graduates are doing should correspond more closely to their highest engineering degrees. This phenomenon was indeed observed. For every group, the percentage of respondents that reported that their occupations were "completely related" to their engineering degrees increased, while the percentage who reported that their occupations were "not at all related" to their degrees decreased (see Table 3). So, while engineering graduates utilize their engineering skills to solve technical problems more now than a decade ago, their skills are being applied to non-technical problems less frequently than before.

The quantitative analysis revealed that there is a narrowing trend in the job descriptions of engineers that occurs on several dimensions: fewer engineers are employed in non-technical jobs, more engineers engage in strictly-technical job responsibilities, and fewer engineers report doing work that is unrelated to their engineering degrees. At first glance, the narrowing trend may seem like good news to engineering educators—engineering graduates are remaining in the field and applying the skills for which they were so meticulously trained. Traditionalists who believe engineering education should *only* entail technical training will find comfort in this trend. Others may celebrate the trend as evidence of an increased "purity" in engineering work. As firm believers in the paramount importance of lifelong liberal education for engineers, the authors find the shrinking job description deeply troubling. Many things, such as an increased demand for technical employees or a decrease in the number of new engineering graduates, could have contributed to this trend. The causes of this trend certainly deserve scholarly attention, though that is not within the scope of this paper. Triangulating the academic backgrounds and interests of the authors, the next section critiques the narrowing trend from the vantage points of industry, education, and society.

Table 3: Change in Responses to "How Similar is Your Job to Your Highest Degree"



Consequences of the Incredible Shrinking Job Description

As an organization dedicated to the advancement and reform of engineering education, ASEE must also commit itself to understanding the occupational world which employs engineering graduates. In this section, the authors draw from various literatures discussing the past and present state of the engineering profession to explore possible consequences for engineering if the narrowing trend continues. The authors postulate that the increasingly technical nature of work that employs engineers will have negative impacts on (1) the advancement of engineering education, (2) the role of engineers in industry, and (3) the social conceptualization of the engineering profession.

Consequences for Engineering Education

Engineering education has always been a delicate balance between the ideals of academia and the needs of industry[4,5]. Many industrial partners depend on universities to provide technical advancements through research and innovation. In turn, universities need to be in line with the expectations of the future employers of their graduates. A narrowing trend in industry could have negative consequences on engineering education by upsetting the academia-industry balance in favor of a heavily-technical and specialized education. The tipping of this balance has

the potential to seriously undermine the foundation for interdisciplinarity and liberal education in engineering, and to hinder the recruitment of women and minority students.

For decades, traditional engineering education has focused on developing students' specialized knowledge so that they may solve challenging technical problems. As a result, engineers are highly trained, but lack some of the skills that make other professionals successful: communication skills, teamwork experience, and societal sensitivity[5,6]. Hoping to remedy this disparity, ABET recently revised its "Criteria for Accrediting Engineering Programs" to require engineering programs to train graduates in teamwork, ethics, communication, and global issues. These changes, though thought to make engineers more well-rounded people and responsible citizens, are given backbone by the widely-held belief that engineering graduates *use* these skills in their work. If fewer engineering graduates are employed in jobs that require them to solve non-technical problems and fewer are using these non-technical skills, our calls for liberal engineering education will stand on even shakier ground.

Furthermore, scales tipped towards a highly-technical industry may invoke extreme specificity in the already-fragmented engineering curriculum[7]. Efforts to retain broadly applicable or interdisciplinary coursework would fight the double currents of narrowly technical engineering jobs and exceptionally specific sub-fields. Since engineering programs are already packed with discipline-specific learning, an increase in technical content or specificity would necessarily come at the expense of broad-based, non-technical education.

If well-rounded engineering education is compromised to meet the needs of an increasingly technical engineering workforce, we may lose more than our battle for liberal education. A more narrowly technical engineering education may hinder the recruitment of women and minority students into these programs. As Seymour and Hewitt and Meadows and Jarema have found, women and historically underrepresented minorities have, on average, more altruistic reasons for choosing engineering than their non-minority peers and are more likely to seek out work that helps them make contributions to their communities and families[6,8]. It is particularly important for women, who enter engineering more attuned to the social responsibilities of engineering, and some minority students, who see engineering as an avenue for advancing the living standards of their group, to understand breadth of occupational options[9,10]. "Traditional engineering curricula, with its emphasis on individualistic and competitive technical training, can mask the importance that this profession has to society and the role that the engineer can play"[8]. A more heavily technical curriculum would make this mask even more impenetrable. Moreover, engineering programs would have a harder time recruiting and retaining students who want a variety of occupational opportunities, or students who are looking to make an important, technically-informed, impact on non-technical spheres.

Interdependency between industry and engineering education is a crucial factor in technological advancements as well as curricular reform[11]. Engineering education has a great potential to shape the next generations of engineers, but it is ultimately responsible to the whims of industry. If engineering work becomes more narrowly technical, engineering education would have little option than to follow suit.

Consequences for Engineering Work

Though the narrowing trend originates from industry forces, it is not necessarily beneficial for engineering as a profession. Engineers' role in industry is a balance between being loyal members of a bureaucratic hierarchy and autonomous members of a profession with its own code of ethics. The more distance industry puts between engineers' technical work and their non-technical, professional identity, the greater the potential for that professional identity to be undermined[12]. The increasingly technical character of industry work may challenge engineers' roles by eroding the boundaries between engineers and technicians, reversing the benefits of the technical career ladder, and reducing engineers' appropriateness for non-technical jobs in the eyes of employers.

As engineering job descriptions become more narrowly technical, engineers' work is likely to be conflated with technicians' work[2,4]. Technicians, though respected and well-compensated, traditionally have much less autonomy and professional voice than engineers. The factors that separate engineers from technicians are precisely those non-technical skills that are at risk if the narrowing trend continues. The conflation of engineers and technicians would reduce the high levels of respect, compensation, autonomy, and responsibility that engineers have enjoyed for more than a century[13].

One factor that attests to the power of the narrowing trend is the increasing popularity of technical career ladders. Utilized in medium and large companies since the late 1980s, the technical career ladder is a separate track devised for science and engineering personnel who want to advance their careers but are dissatisfied with the strictly managerial positions at the top of traditional corporate ladders. These career ladders were intended to allow strong technical workers to remain in technical positions while working towards becoming experts within their companies[14,15,16]. Higher-level people on the technical career ladder often mentor, consult, and manage other technical employees, all the while, gaining the monetary and emotional rewards of moving up in their careers. Though devised to maximize productivity and employee job satisfaction, the technical career ladder misleads employees to believe they can avoid developing non-technical skills such as communication and managerial skills. In actuality, as engineers progress through the technical career ladder, soft skills will still be required to effectively manage and mentor other technical employees and relay ideas to non-technical co-workers.

These strictly-technical tracks, though developed for the benefit of the company and the employee, risk several consequences. First of all, engineers in technical tracks can become pigeonholed in one part of a project, alienating them from other technical and non-technical components. This pigeonholing can also threaten job satisfaction by reducing engineers' sense of contribution and ownership to a final product. Secondly, the technical tracks breed loss of perspective regarding business goals and product marketability. Third, because engineers in a technical track may rarely work with non-technical staff, their ability to effectively communicate technical ideas across boundaries to less-technical branches of the company are compromised. Finally, and most seriously, strictly-technical career tracks remove engineers from the big picture and reduce their ability to serve as effective whistleblowers—an important piece of their professional identities.

Beyond issues of productivity, the narrowing trend in industry threatens several facets of the engineering profession. Because engineers are intimately connected with new technologies, they have unprecedented insight into the capabilities of these technologies to help or hinder society. It is imperative that engineers' perspectives on these matters be heard. If the engineering profession is seen by industry to be applicable only to an increasingly narrow set of technical problems, then the strength of engineers' voices on matters of ethics and social responsibility may decline [4, 17, 18, 19] . Additionally, engineering-like skills and thinking are in great demand in public policy and the legal fields [3, 20]. As engineers are restricted to technical work, their problem solving skills will be seen as less and less appropriate for non-technical problems. If the technical work for which engineers are experts upsets the balance between professional autonomy and bureaucratic loyalty, engineering's professionalism is at stake.

Consequences for the Social Conception of Engineering

The final set of consequences of the narrowing trend concerns the social conception of the engineering profession. The public understanding and trust of engineers, and indeed engineers' own conceptions of their discipline, are paramount to the profession's success and vitality. If the narrowing trend continues, engineering could face the destabilization of its professional identity, further disciplinary fragmentation, and threats to its social status.

The social conception of engineering has been anchored in a "savior" ideology since the 19th century. Engineering has been seen by the public (and by the engineers themselves) as the savior of humanity from darkness, natural disasters, boredom, and national enemies. Though this cultural image has fluctuated over the decades, complicated by other imagery like the "nerd" stereotype, it is the keystone of engineers' pride in their professional identity[2,21]. Though the savior imagery is idealistic, it serves an important function in engineering as a rallying ideology for ethical and socially-conscious problem-solving. If engineers become increasingly associated with narrowly technical work, and less associated with general problem-solving tasks, their "savior" identity may be jeopardized. Furthermore, an increased association with technical work may bolster the stigma of engineering as an anti-feminine profession—making it even more difficult to recruit and retain women engineers[22,23].

As discussed in the subsection on engineering education, narrowly technical job descriptions would be accompanied by hyper-specialization. Such specialization would strain the already-thin threads of professional unity that weave together engineers from different sub-disciplines. Disciplinary fissures would deepen while knowledges would become more localized, making interdisciplinarity even more difficult[11,22,24].

Finally, increasingly technical work for engineers may threaten the high social status that they enjoy. If engineering work is conflated with technicians' work, then the professional respect and autonomy that engineers benefit from may wane. Furthermore, engineers may become so deeply associated with technical problem-solving that there is little opportunity for them to step into non-technical decision-making positions[4,17].

Conclusions

The consequences presented in this article are supported by a wide variety of literature, but any discussions of future trends are ultimately speculative. No one can know for sure whether the narrowing trend will continue, and if it does, whether it will accrue these consequences. However, effective education practices cannot be developed without a certain amount of speculation. The authors hope that this article invokes thought about where engineering education is currently, and where it must go in the future. Engineering education cannot single-handedly halt the narrowing trend, but neither is it completely powerless. Recent literature in the spirit of *The Engineer of 2020* has given researchers and educators a myriad of suggestions for graduating ethical, socially-conscious engineers. By utilizing these suggestions, engineering education can produce engineers who understand the importance of well-rounded knowledge for both themselves *and* their profession. Training this generation's engineering graduates to be responsible for the direction of the profession's future can help ensure that the negative consequences suggested here do not come to fruition.

The authors have attempted to raise sound the alarm about a current trend in engineering work. At the very least, this study can be used as a tool to help administrators and faculty convince their more traditional colleagues of the need for well-rounded and socially-informed engineers.

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