Perspective: 2013 Professional Progress Award

The Evolving Engineer

Amalie L. Turek and Kelvin H. Lee
Dept. of Chemical and Biomolecular Engineering and Delaware Biotechnology Institute, University of Delaware, Newark, DE 19711

DOI 10.1002/aic.14461
Published online April 17, 2014 in Wiley Online Library (wileyonlinelibrary.com)

Keywords: science and technology policy, public engagement, broader impacts, communication, engineering education

Introduction

Chemical engineers have been key players in developing much of the technology essential to the operation of modern society. Yet many chemical engineers (at least in the United States, the focus of this article) have traditionally kept themselves at arm's length from the sociological and political issues related to technology deployment (Figure 1A), which require interactions with other segments of society (i.e., policy, education, public relations, and medicine, among others).[1] Engineering involvement in public policy and in discussions prioritizing national research has typically occurred only when cuts in government research funding appeared imminent.[2]

However, current issues urgently requiring solutions from the international engineering community are increasing in complexity and scale, including the imperatives to develop safe and sustainable food and water supplies, make solar energy economical, and engineer better medicines.[1,3] Solutions to these complex issues require systems thinking and engineering design that consider political, social, and economic constraints, as well as the obvious technical challenges.[4] Engineering principles must be integrated with other forms of knowledge (insight, historical experience, ethics, etc.)[5] to help better understand and respond to the rapid changes of today's world, to inform policy that will both benefit society and foster engineering innovation,[6,7] and to guide future engineering research initiatives that will secure the relevance of our profession.

Thus, the scope of involvement for the chemical engineering professional is evolving—we now need to effectively engage, communicate, and work in concert with policymakers, social science professionals, and members of other disciplines (Figure 1B), despite challenges posed by different perspectives, values, tools, and language.[8] *We need to train and develop chemical engineers able to bridge this divide and able to operate in a role increasingly entwined within society and policy.*

Correspondence concerning this article should be addressed to K. H. Lee at KHL@udel.edu.

The Evolving Engineer

Although depth of engineering knowledge is still paramount, employing only technical criteria in engineering design is insufficient for the development of successful solutions for our evolving, complex society. Political and social issues are important constraints in modern engineering design problems, and these concerns must be incorporated into engineering systems thinking.[9] For example, building design previously emphasized visual impact over function,[10] producing societal icons such as New York City's original World Trade Center. These buildings offered protection against certain hazards (e.g., fire, earthquakes) as required by local building codes, but certain design aspects, such as energy efficiency or the building's indoor ecology, were of secondary importance.[10] However, changes in political, social, and economic forces have reshaped building design principles. Because iconic buildings and structures which provide critical infrastructure have become targets of terrorism, buildings are now being designed to preserve as many lives as possible (via fire-resistant construction materials, improved egress routes) and to resist multiple hazards before catastrophic failure.[11] Rising energy costs and increased prevalence of health issues associated with environmental factors (e.g., asthma) have shifted building design toward applying leadership in energy and environmental design (LEED) principles; opportunities for chemical engineering contributions on this front were described in a previous AIChE perspective.[10]

Other examples of the interplay between chemical engineering design and societal or political issues abound. For instance, the development of microfluidic systems has been driven by demand for health diagnostics intended for use in military environments and developing countries, which lack infrastructure such as air-conditioned labs, refrigerated storage, and highly trained medical personnel.[12] Government initiatives to bring critical natural resources under domestic control have spurred major investments in related technologies; in Israel, a shortage of freshwater sources motivated the development of large-scale desalination facilities,[13] and a push for energy independence in the United States escalated research into new energy sources (i.e., unconventional

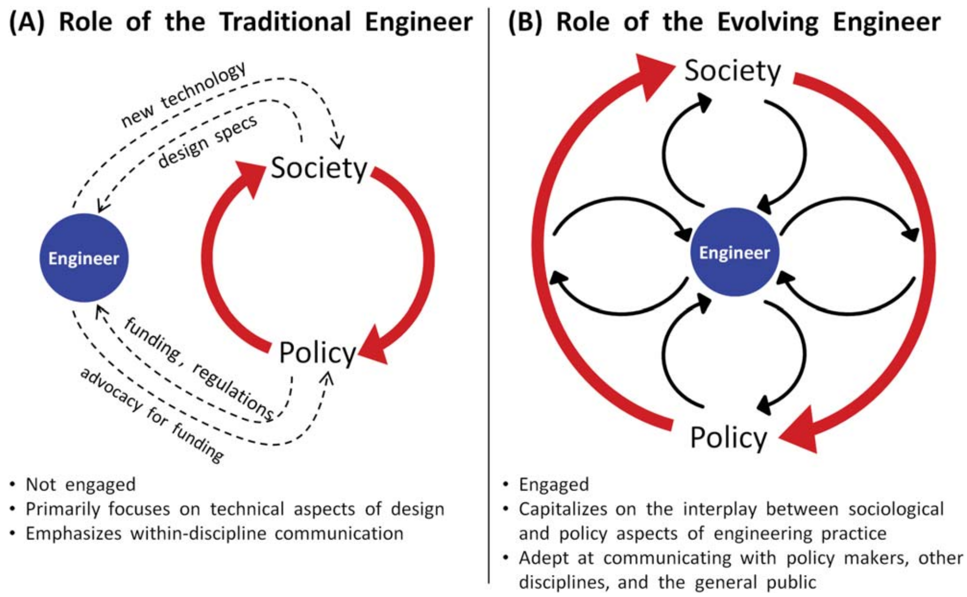

Figure 1. Historical and future roles for engineers in technology deployment and technology policy.

(A) While engineers have typically kept at arm's length from social and policy issues, (B) the Evolving Engineer needs to facilitate technological advances through a systems approach which considers political and social forces in technology development and deployment, and which capitalizes on the interplay between policy, society, and engineering practice.

natural gas, renewables, etc.).[14] These examples all demonstrate how the ability to synthesize the technical aspects of engineering with policy, culture, religion, the arts, and economics is a critical skill for the successful modern engineer.

The Evolving Engineer must capitalize on the interplay between good engineering design and political, social, or cultural concerns. This requires a high level of technical aptitude as well as competence in:

- understanding the broader political and social context of engineering practice,
- collaborating with a range of disciplines, including policymakers, and
- communicating effectively with a broad cross section of society.

Nonetheless, it is not clear if current engineering curricula and training provides students with enough training in these areas to help them innovate solutions for our changing world. Part of the challenge is that the development of these skills should not come at the expense of reduced technical competence.[15] In the following sections, we describe current shortcomings, make recommendations for improving training in these areas, and provide examples of development opportunities (see Table 1) for the Evolving Engineer.

A Broader Context of Engineering Practice

Understanding the nature of relevant political and social issues is a prerequisite to good engineering design, thus requiring an appreciation for, and competence in, basic policy, social science, and cultural studies among engineers

As an example of how this issue will manifest itself, it is projected that within the next 20 to 30 years English will no longer be the most common language (Katehi, in [16]), yet foreign language requirements in United States postsecondary engineering curricula have all but been abolished.[9] Engineering undergraduates interested in studying abroad often struggle to integrate this experience into their education without significantly extending degree timelines due to rigid prerequisites and the constraints of course offerings.[9] Furthermore, few United States undergraduate or graduate engineering programs integrate policy or social science studies into the core engineering curricula[17] (the few that do are discussed later in this section). Instead, general education requirements in the humanities, social sciences, and arts are sometimes regarded as obligatory check-boxes for an engineering bachelor's degree, with no direct relevance to engineering coursework. Unfortunately, the failure of engineering educators to connect engineering practice with its social context may actually contribute to the low retention rate in engineering programs, where students aspiring to help people and society struggle to see how their engineering studies (and all of those initial technical courses) will provide these opportunities.[9,17]

The most recent data from the science and engineering statistics (SESTAT) database[18] (survey years 2003, 2006, 2008, 2010) suggest that a genuine emphasis on social science-related studies* together with an engineering education provides a broader political and social context for engineering practice. Few engineering degree holders also hold degrees in social science-related fields (Figure 2A; 0.88% across all engineering disciplines and 0.54% for chemical engineering). However, individuals who do hold both engineering and social science-related degrees are approximately two times more likely to be employed in the government

*These include economics, political science, psychology, anthropology, and "other" social sciences

Table 1. Opportunities for the Evolving Engineer

Opportunity Type	Time Required	Experience Required	Opportunities	Development Areas Addressed: Social Context	Collaboration	Communication
Self-guided Study	Low	Low	Science & technology legislation tracker: • www.aaas.org/page/legislation-trackers	X		
			Policy guides for engineers and scientists: • Working with Congress: A Scientist's Guide to Policy: www.aaas.org/page/working-congress-scientist%E2%80%99s-guide-policy • Engineer's Guide to Influencing Public Policy: www.ieeeusa.org/policy/guide/index.html	X	X	X
			Create short videos that explain the relevance and basic principles behind scientific research and engineering efforts; see reference[38] for guidance	X		X
Immersion Experiences	Med	Low	Workshops & short courses: • Science Policy Bootcamp: www.mitspi.org/#!bootcamp/cfhf • Science Outside the Lab: http://cspo.org/outreach/science-outside-the-lab	X	X	
Organized Forums	Low	Med	Forums promote dialogue between the technical community and the policy arena: • Congressional Visit Day: www.setcvd.org/ • Research Partners Forum: www.researchamerica.org/forums			X
Outreach to the General Public	Low-Med	Low-Med	Many institutions have established programs where you can participate in opportunities that suit your own skills, strengths, and interests;[8] examples include: • advising a student in or judging for a local science fair • volunteering at a science or engineering camp • hosting school groups for field trips and tours	X		X
Policy Internships & Fellowships	High	Low-Med	Opportunities to work directly within policy-making bodies (access a comprehensive list at www.science-policy.net/11627.html): • Washington Internships for Students of Engineering (undergraduate): www.wise-intern.org/ • Office of Science and Technology Policy Internships (graduate & undergraduate): www.whitehouse.gov/administration/eop/ostp/about/student • Christine Mirzayan Internship Program (graduate & post doc): www.nationalacademies.org/policyfellows/ • Presidential Management Fellows Program (graduate): www.pmf.gov/ • AAAS Science and Technology Policy Fellowships (Ph.D. graduates & experienced professionals): www.aaas.org/program/science-technology-policy-fellowships • Jefferson Science Fellowship (tenured faculty): http://sites.nationalacademies.org/pga/jefferson/	X	X	X
Direct Outreach to Policymakers	Med-High	High	These opportunities[2,5,9] are best for engineers with previous policy experience: • meet with your local representatives to discuss issues about which you are concerned or interested • volunteer as a science/technical advisor to local elected officials and candidates	X	X	

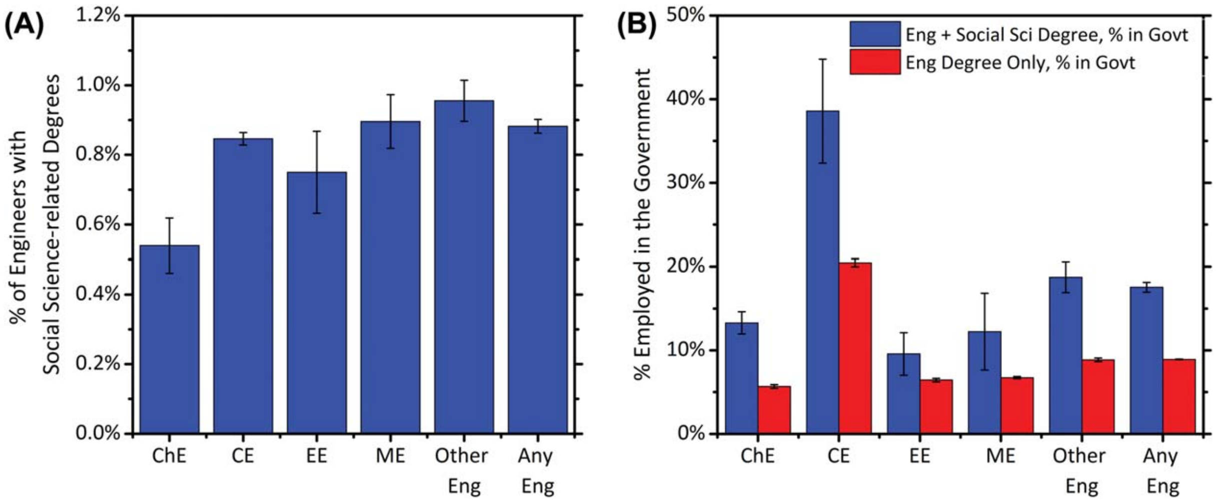

Figure 2. (A) Percent of individuals with engineering degrees also holding a social science-related degree, and (B) comparison of government employment rates among engineers with and without additional social science-related degrees.

In all cases, the values presented are the average of the four most recent SESTAT survey years for which these data are available (2003, 2006, 2008, 2010).[18] Error bars represent the standard error of the values across the four surveys.

(Figure 2B). Although this may reflect a self-selected group, it also is consistent with the idea that students trained in social sciences and engineering are better prepared for positions involving policy and social engagement.

There is an expanding movement to integrate social concerns into engineering systems thinking, design criteria, and problem solving.[19,20] The current ABET criteria for engineering education require political, social, and ethical topics be included in the set of "realistic constraints" for consideration in engineering design.[21] These criteria also stipulate that "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" be incorporated into the undergraduate engineering curricula. A report from the National Academy of Engineering (NAE), *The Engineer of 2020: Visions of Engineering in the New Century*, discusses the societal, global, and professional contexts of engineering practice and recommends improved integration between engineering, social concerns, and policy-making.[4]

Educational paradigms should reinforce the interplay between engineering, policy, and society by framing engineering problems in a social and political context throughout an engineer's education.[15] Such training may enable engineers to determine how and when to incorporate social elements into the systems analysis of their work.[4] Of course, simply requiring additional coursework for engineering students is not practical, as the current undergraduate engineering curriculum is perceived as overloaded[4,16] and tuition is expensive. Moreover, relying on general education courses that do not reflect on the connection of science and engineering with society, culture, language, etc., would probably not yield an integrated educational experience for students anyway. Hyman describes one solution: the use of engineering design education as a logical platform for integrating public policy considerations into the engineering curriculum, providing specific, concrete suggestions that include topics for design projects, homework assignments, and test questions.[15] However, Hyman cautions that the integrated treatment of social criteria in engineering design courses will only be meaningful if students have previous exposure to these social dimensions of design. Therefore, we can no longer afford for studies that provide political, social, and global context for engineering practice to remain fully subordinate to technical courses in engineering education.

Examples of diverse approaches to the integration of social science, policy, and cultural studies can be found in Table 2; these range from optional enrichment programs to mandatory training within the engineering curriculum. A particularly interesting one (described in detail by Kerns et al. in [16]) is the model of Franklin Olin College of Engineering, where engineering coursework is integrated with design projects and social studies during all 4 years of the undergraduate program, and students are encouraged to pursue extracurricular artistic or entrepreneurial interests to foster their creative edge.

Increased Collaboration

To successfully develop and implement novel technologies addressing global challenges, chemical engineers must increase collaboration with policy makers and other disciplines

The concept that engineers have a responsibility to focus their efforts toward solving societal issues is not new.[6,19,20,22] Current chemical engineering research efforts have clear implications in more than half of the Grand Challenges for Engineering identified by the NAE.[3] However, successful deployment of many new technologies (that address topics such as energy, water and food supply, and global health issues) requires a coordinated effort between engineers, policymakers, scientists, economists, and social scientists (among other groups) at all stages of research, development, and deployment.[1] In particular, the role that

Table 2. Engineering Program Examples that Promote Incorporation of Policy, Social Science, and/or Science, Technology, and Society (STS) Coursework and Enrichment Experiences into Engineering Education

Institution	Program Name	Description
Carnegie Mellon University	Department of Engineering and Public Policy	Actively researches and promotes the engineering-policy interface through: • a research-oriented Ph.D. program • double-major degree for engineering undergraduates • an office in Washington, DC to expand interaction with policy organizations
Franklin Olin College of Engineering	N/A	Integrates engineering coursework with: • hands-on design projects in every year and capstone projects • social sciences and humanities coursework • foundations of business, entrepreneurship, and innovation • international/intercultural immersion experiences
Massachusetts Institute of Technology	The Science Policy Initiative	Student-run enrichment program that educates and promotes interaction between MIT engineers/scientists and policymakers/public through: • graduate Certificate program in Science, Technology, and Policy • Science Policy Bootcamp short course • opportunities for students to visit Washington, DC via Congressional Visit Day and Executive Agency Visit Day
Stony Brook University	Department of Technology and Society	Administers degree programs, conducts research, and promotes outreach: • Ph.D. in Technology, Policy & Innovation • M.S., B.S., and Minor in Technological Systems Management • STEM Smart outreach program for mentoring underrepresented and disadvantaged students in STEM (science, technology, engineering, and mathematics) fields
University of Maryland	Science, Technology and Society Programs	Optional undergraduate enrichment program for engineering and non-engineering students: • living/learning undergraduate immersion program in STS • undergraduate certificate in STS
University of Virginia	Department of Engineering and Society	Provides a mandatory basis in STS studies for all undergraduate engineering students, including: • required STS courses in the 1st and 4th years and other STS electives • three undergraduate minor degree programs • optional internship program in science and technology

government and public policy play in technology development and deployment is increasing in importance and complexity,[23] emphasizing the need for collaboration between engineers and policymakers. This type of engagement is much different and deeper than the current approach used by many engineering academics to simply advocate for increased research funding.[2,4]

Technological and scientific considerations are central to many, if not most, of the policy decisions facing current legislators.[23] However, a potential barrier to creating effective technology policies, particularly in the United States, is the lack of technical backgrounds[24–26] among legislators and elected officials. Members of recent Congresses listing the occupation of "engineer" ranged from zero (2001–2004) to six (1.1%; 2009 to present),[27–33] and the number of scientists was similarly low. Another report counts 15 current Congressmen who have "engineering backgrounds" (14 representatives and one senator; 2.8%), which includes both career engineers as well as engineering degree holders who worked in other fields.[26] The presence of, or lack thereof, legislators with engineering backgrounds at the state level is similar; in 2007 only 1.6% of state legislators across the nation listed their occupation as scientist, engineer, or architect,[†] and 11 states had no engineering or science representation at all.[34]

In legislation dealing with complex, global systems where it is essential to incorporate technology considerations and technical knowledge, there is a place for the analytical attributes of engineers to help frame and present policy options to policymakers.[5] For example, in developing science and technology legislation, the job of Congressional committees and their staffers is not to understand every scientific principle underlying the policy issues at hand (Byerly and Sarewitz in [35]). Instead, the role of Congressional committees responsible for science and technology legislation is to effectively use the legislative system to provide for and support engineering and science activities.[35] To enable this, Congress must have access to relevant and credible technical information that "matches the language and policy context of congressional deliberation" and "informs policy issues without necessarily recommending specific actions."[23] Here, the engineering community could play a key role by helping identify and define the policy options available, by predicting the implications of those options (including advantages, risks, and costs), and by providing an analytical approach to decision-making.[8,19,36] The systems-thinking approach of engineers would need to incorporate technical, policy, sociological, and economic considerations simultaneously into engineering design and understand their implications, requiring improved engagement and collaboration on both the policy and societal fronts (Figure 1B).

The primary concerns of policymakers are the inputs and outputs of a system, rather than its internal workings. Therefore, engineers may need to become skilled at using their deep technical knowledge to provide the answers to questions that policymakers need without complicating their messages with technical details. Table 1 provides resources for improving collaboration skills, including policy guides and

[†]A more detailed breakdown of science and engineering occupations among state legislators is not available

workshops, and also suggests opportunities for increasing collaboration with policy makers.

Improved Communication

For engineers to influence public policy toward advancing technology, our community must develop a capacity for communicating to a broad cross section of society

We are not alone in believing that effective communication with policy makers,[5,37] other professions,[6] and the general public[7,38] is the most significant development area for the evolving engineer. Currently, communication training for engineering students focuses on writing and presentation skills best suited to convey within-discipline messages. Strategies for communicating with other disciplines, policy makers,[8,39] or the public are not generally emphasized; engaging in effective dialogue with these groups requires a vastly different approach.

Communication with other disciplines

Underlying the communication barrier between engineering and nontechnical communities are inherent differences in what constitute the most valuable and effective communication strategies. The most successful among politicians, policymakers, and lawyers recognize that people typically only absorb information they perceive as personally valuable.[6] Thus, these professions excel at interpreting the needs of diverse audiences and tailoring messages accordingly. The most successful engineers and scientists, on the other hand, often excel at communicating to peers. Publishing technical literature, delivering engaging lectures, and crafting effective proposals to garner funding are essential communication skills—*within* the technical community.

Communication strategies used in the technical world hinder the engineer's ability to inform in the policy arena. Detailed technical information obscures messages to policymakers,[5] whose immediate goal is decision making[40] and for whom attention (not information) is the limiting resource (Byerly in [35]). A more effective approach is to provide only the most critical information, crafted into counsel that provides a guide to action.[35] Another peril of a technical mindset is the expectation that scientific facts will speak for themselves, point to the 'correct' solution, and convey urgency on their own merit.[35,37] In reality, the outcome of policy conflicts is at least as dependent on style and tactics as on the facts,[37] as illustrated by Robert Palmer's recollection of the Ocean Dumping Act's passage in Congress (Staff Director for the U.S. House Committee on Science and Technology, 1993–2004):

> "Now when a vote is taking place on the floor, the sponsors of the legislation typically stand near the entrances to the chamber and explain the gist of the bill to the entering Members. I expected to hear (his boss Jerry Ambro) saying something like, "Vote yes and you can expect that mercury, cadmium, and lead levels in the sediments of Long Island Sound will slowly decline over the next 50 years." Instead Mr. Ambro came up with something much catchier: "Vote 'Yes' for Clean Fish." A Member sitting near me looked up at the electronic board displaying each Member's vote, turned to another Member sitting next to him, and said, "You just voted for dirty fish." That Member, horrified, quickly reinserted his voting card and got back on the clean-fish bandwagon."[35]

To effectively engage with policymakers and other nontechnical professions, engineers must hone these skills. Training should be incorporated into the engineering curriculum by expanding communication courses to cover strategies appropriate for interdisciplinary scenarios and explaining the need to use different communication strategies for different audiences. Professional engineers can refine their communication skills through self-guided study and by engaging with policymakers and other professions through opportunities such as organized forums or policy internships and fellowships (see Table 1 for resources and more examples).

Communication with the general public

Because major initiatives often cannot succeed without public support,[5,41] the engineering community should strive to raise awareness of scientific issues among the general public and endow them with urgency, in addition to attempting to raise the level of scientific literacy.[5] This effort requires that both the content and style of the message be tailored to the general public. The content must address the public's primary concerns: "How does this issue affect me, my community, and my world?"[5] Technical jargon, acronyms, and complex words obscure the message, and should be minimized or eliminated.[6]

The style of the message is even more important. Randy Olson, a marine biologist-turned filmmaker, describes the disparity between the communication styles of the technical community and the general public in very simple terms: the technical community operates in the *head* (logic, reason, and analysis), whereas most of the public respond best to messages aimed at their *hearts* (passion and emotion), *guts* (humor and instinct), and *sex organs* (which have no logic at all).[38] Although making technical messages "sexy" may be unrealistic for many issues, effective stylization can help ensure the impact of our messages in the public sphere. An exercise recommended by Olson (and something we have found challenging for us in our own research group) is the creation of a short (1 min) video that describes the relevance and basic scientific principles of a (for example, graduate student's) research project.[38] This movement has gained recent momentum; organizations such as the NAE and the NSF have recently sponsored contests seeking student-made videos aimed at a general audience that describe research initiatives and explain the importance of engineering efforts.

Improved communication and engagement with the general public will help increase the visibility of engineers and engineering endeavors. Unlike professions that work one-on-one with people (e.g., physicians and lawyers), many engineers are tucked away in industry and academic labs, working only with equipment and data. Thus, members of the public often have poorly formed ideas of what engineers do, how they serve society, and what an engineering education can offer.[16] For example, while it is easy to see the impact that doctors have in treating disease, the roles that engineers and scientists have played in developing life-saving medicines (improving methods of production, designing manufacturing facilities, and innovating new delivery methods) are less obvious. Professional engineering societies provide an important means for giving a voice to engineers and for shaping their messages. For instance, AIChE's efforts on this front are channeled through its public affairs and information committee. Examples of other opportunities for outreach with the general public are provided in Table 1. Successful efforts to communicate and engage with society beyond the engineering community will better showcase what engineers do, demonstrate why engineering is important, and help recruit creative minds to the next generation of engineers.

Conclusion

Neal Lane, science advisor for President Clinton, used the term "civic scientist" to describe one "who uses his or her knowledge, skills, or fame to reach out to the public and policy makers to improve their understanding of science and technology and to influence important public policy."[35] We envision similar qualities for the Evolving Engineer. However, we believe there is another, more concrete motivation for the engineer's evolution: addressing global issues and developing an improved social perception of engineering practice is a matter of survival for our profession.[16]

Chemical engineering, and all of engineering, must evolve. We should embrace and emphasize the role of political and social issues with equal importance as technical and economic issues. We need to inspire the next generation of engineering students to contemplate their role as engineers in society from their first day as a student. Indeed, doing so may help diversify our profession and help attract even better students.[9] Engineers should be excited to share the relevance of their work to society as a whole, and should be trained to do so in addition to their training in technical communication. It is a challenge to craft communication strategies to cope with the disparity in perceptions, languages, and timelines between the technical and policy realms, but this is important to our students and profession. Ultimately, if we do not present our knowledge in a way that enables action toward solving societal problems, our scientific discoveries and engineered solutions have not succeeded.[42] Furthermore, if we do not fully consider the political, social, and cultural context of engineering practice, we risk developing suboptimal solutions to the grave issues facing our society.

Acknowledgments

We would like to thank Thomas Powers for discussing concepts and providing suggestions that helped shape this article, as well as the reviewers for their wonderful insights. We gratefully acknowledge funding from the National Science Foundation (1144726 and 0750966).

Literature Cited

1. American Institute for Medical and Biological Engineering. Medical and biological engineering in the next 20 years: the promise and the challenges. *IEEE Trans Biomed Eng*. 2013;60(7):1767–1775.
2. Lawler A. Robert Walker: The speaker's right hand on science. *Science*. 1995;269:749–751.
3. National Academy of Engineering. *Grand Challenges for Engineering*. Washington, DC: National Academies Press; 2008. Available at: http://www.engineeringchallenges.org/?ID=11574. Accessed February 3, 2014.
4. National Academy of Engineering. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: National Academies Press; 2004.
5. Yankelovich D. Winning greater influence for science. *Issues Sci Technol*. 2003;19(Summer).
6. Galloway PD. *The 21st Century Engineer: A Proposal for Engineering Education Reform*. Reston, VA: ASCE Press; 2008.
7. Mooney C, Kirshenbaum S. *Unscientific America*. New York: Basic Books; 2009.
8. Fox JJ. Science policy matters: Observations from two years in Washington, DC. *Acoust Today*. 2011;7(2):25–33.
9. Tirrell M V. Does the U.S. style of chemical engineering education serve the nation well? In: Burland DM, Doyle MP, Rogers ME, Masciangioli TM, eds. *Preparing Chemists and Chemical Engineers for A Globally Oriented Workforce*. Washington, DC: National Academies Press; 2004:39–44.
10. Foley HC. Challenges and opportunities in engineered retrofits of buildings for improved energy efficiency and habitability. *AIChE J*. 2012;58(3):658–667.
11. Sternberg E, Lee GC. Meeting the challenge of facility protection for homeland security. *J Homel Secur Emerg*. 2006;3(1):Article 11.
12. Yager P, Edwards T, Fu E, et al. Microfluidic diagnostic technologies for global public health. *Nature*. 2006; 442(7101):412–418.
13. Stratfor. Israel's Water Challenge. *Forbes*. http://www.forbes.com/sites/stratfor/2013/12/26/israels-water-challenge/. Published Dec. 26, 2013. Accessed March 12, 2014.
14. Salameh MG. The new frontiers for the United States energy security in the 21st century. *Appl Energy*. 2003; 76(1-3):135–144. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0306261903000540. Accessed February 11, 2014.
15. Hyman B. Public policy and engineering design education. *Int J Eng Educ*. 2003;19(1):110–117.
16. National Academy of Engineering. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press; 2005.
17. Ngambeki I, Evangelou D, Rao S, Cox M, Behbehani L. Work in progress - developing a curriculum to prepare engineers to participate in public policy. In: 41st ASEE/IEEE Frontiers in Education Conference; October 12-15, 2011; Rapid City, SD. T4F1-T4F2.
18. National Science Foundation National Center for Science and Engineering Statistics. Scientists and Engineers Statistical Data System (SESTAT), [2003, 2006, 2008, 2010]. Available at: http://www.nsf.gov/statistics/sestat/. Accessed January 31, 2014.
19. Weingardt RG. Leadership: the world is run by those who show up. *J Manag Eng*. 1997;13(6):61–66.
20. Emison G. Civil engineers and future environmental policies. *J Prof Iss Eng Ed Pr*. 2001;127(3):130–138.

21. Engineering Accreditation Commission. 2014–2015 Criteria for Accrediting Engineering Programs. Baltimore, MD: ABET; 2013. Available at: http://www.abet.org/eac-criteria-2014–2015/.
22. Zolandz D. Broader impact through the national academies. *AIChE J*. 2007;53(2):276–280.
23. Blair P. *Congress's Own Think Tank: Learning from the Legacy of the Office of Technology Assessment (1972–1995)*. New York: Palgrave Macmillan; 2013. doi: 10.1057/9781137359056.
24. Augustine N. Danger: America is losing its edge in innovation. *Forbes*. http://www.forbes.com/sites/ciocentral/2011/01/20/danger-america-is-losing-its-edge-in-innovation/. Published January 20, 2011. Accessed January 30, 2014.
25. Paulos JA. Why don't Americans elect scientists. *The New York Times*. http://campaignstops.blogs.nytimes.com/2012/02/13/why-dont-americans-elect-scientists/. Published February 13, 2012. Accessed February 3, 2014.
26. Palmer D. Slideshow: An Engineer Goes to Congress. *DesignNews*. 2013. Available at: http://www.designnews.com/author.asp?section_id=1365&doc_id=263895. Accessed January 30, 2014.
27. Amer ML. *Membership of the 107th Congress: A Profile*. Washington, DC: Congressional Research Service; 2001. RS20760. Available at: http://digital.library.unt.edu/ark:/67531/metacrs1517/m1/. Accessed March 14, 2014.
28. Amer ML. *Membership of the 108th Congress: A Profile*. Washington, DC: Congressional Research Service; 2004. RS21379. Available at: http://www.senate.gov/reference/resources/pdf/RS21379.pdf. Accessed March 14, 2014.
29. Amer ML. *Membership of the 109th Congress: A Profile*. Washington, DC: Congressional Research Service; 2006. RS22007. Available at: http://www.senate.gov/reference/resources/pdf/RS22007.pdf. Accessed March 14, 2014.
30. Amer ML. *Membership of the 110th Congress: A Profile*. Washington, DC: Congressional Research Service; 2008. RS22555. Available at: http://www.senate.gov/reference/resources/pdf/RS22555.pdf. Accessed March 14, 2014.
31. Manning JE. *Membership of the 111th Congress: A Profile*. Washington, DC: Congressional Research Service; 2010. R40086. Available at: https://www.senate.gov/CRSRe ports/crs-publish.cfm?pid=%260BL)PL%3B%3D%0A. Accessed March 14, 2014.
32. Manning JE. *Membership of the 112th Congress: A Profile*. Washington, DC: Congressional Research Service; 2012. R41647. Available at: https://www.senate.gov/reference/resources/pdf/R41647.pdf. Accessed March 14, 2014.
33. Manning JE. *Membership of the 113th Congress: A Profile*. Washington, DC: Congressional Research Service; 2013. R42964. Available at: http://www.fas.org/sgp/crs/misc/R42964.pdf. Accessed March 14, 2014.
34. National Conference of State Legislatures. Legislator Demographics. 2014. Available at: http://www.ncsl.org/research/about-state-legislatures/legislator-demographics.aspx. Accessed January 22, 2014.
35. Pielke RJ, Klein RA, eds. *Presidential Science Advisors: Perspectives and Reflections on Science, Policy and Politics*. In: New York: Springer Science & Business Media B.V.; 2010.
36. Banholzer WF, Jones ME. Chemical engineers must focus on practical solutions. *AIChE J*. 2013;59(8):2708–2720.
37. Tribus M. The engineer and public policy-making. *IEEE Spectr*. 1978;15(4):48–51.
38. Olson R. *Don't Be Such a Scientist: Talking Substance in an Age of Style*. Washington, DC: Island Press; 2009.
39. Mathews DJH, Kalfoglou A, Hudson K. Geneticists' views on science policy formation and public outreach. *Am J Med Genet*. 2005;137(2):161–169.
40. Wright D. Bridging the gap between scientists and policy makers: whither geospatial? *Esri*. 2013. Available at: http://blogs.esri.com/esri/esri-insider/2013/02/11/bridging-the-gap-between-scientists-and-policy-makers-whither-geospatial/. Accessed January 19, 2014.
41. Moss RH, Meehl GA, Lemos MC, et al. Hell and high water: practice-relevant adaptation science. *Science*. 2013;342(6159):696–698.
42. Campbell T. The problem of boring science. *News Obs*. 2013. Available at: http://www.newsobserver.com/2013/12/26/3486614/the-problem-of-boring-science.html. Accessed January 30, 2014.