

# Defining Engineering Thought\*

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*There is a national crisis in engineering and a compelling need to reconsider and rejuvenate engineering education. Shortcomings in engineering education have been identified by the National Academy of Engineering, the National Research Council and the National Science Foundation, among others, and are marked by an extremely narrow approach to education, inadequate preparation of engineers to function in multidisciplinary contexts, and practices that are exclusionary to women and under-represented minorities. These symptoms of a less than optimal education system underscore the pressing need for the realignment of engineering education. The Picker Engineering Program at Smith College is at the forefront of change in engineering education, as the first institution to establish an engineering program at a women's college, the first institution to establish a faculty position with a dual appointment in engineering and education and the first institution with an engineering faculty that is more than 50% women. The Picker Engineering Program promotes engineering as a liberal art and as a profession in service to humanity. We believe that both these tenets are vital not only to the success of the program but also to the engineering profession and the comprehensive education of our youth. Smith College hopes to take this transformation of engineering education outside its walls and develop strategies and innovative pedagogy (K-16) to address the severe lack of quantitative literacy across society and to inspire a new generation of liberally educated engineers. Founded in 1999, the Picker Engineering Program has stepped to the forefront of engineering education—attracting national attention from the academic and professional circles, and support from a number of companies including Ford Motor Company, Bechtel, Hewlett-Packard, the GE Fund, and Boeing. The Picker Engineering Program supports research and activities that: develop an exciting, learner-centered engineering curriculum that engages and challenges students; develop an integrated curriculum that fosters a mastery of engineering fundamentals within the context of the liberal arts; encourage socially responsible and sustainability-centered thinking; develop socially and personally relevant curricula to attract and retain women and under-represented minorities; and encourage and develop the language of technology and quantitative literacy among non-engineering majors.*

## INTRODUCTION

IN RECENT YEARS, much attention has been focused on the need to expand and enhance our engineering workforce. While there is a fair body of work that identifies problems in engineering education, few initiatives have been enacted to directly address these shortcomings. To date, most successful initiatives in engineering have been short-lived and/or have lacked national reach. Programs such as those which existed at UC Santa Cruz and UC Berkeley in the 1990s (both led by Karl Pister, Chancellor-emeritus of UC Santa Cruz and Dean of Engineering at UC Berkeley) saw great success in increasing the number of women and under-represented minorities in engineering. Because of the structure of these initiatives, the passing of California Proposition 209 (prohibiting preferential treatment by state and other public entities) crippled these programs and prevents their replication, at least in California. Other successful initiatives, specifically those that combine engineering with other quantitative disciplines (usually labeled 'SMET'—Science, Math, Engineering and Technology),

derive their success in science and math but make little or no progress in engineering. For example, Project Kaleidoscope, founded in 1989 to address educational reform in SMET and set an agenda for action, sponsors forums and workshops, and develops publications. While disciplines in the sciences and math are filled with publications, after more than a decade only one significant publication is listed as engineering.

The Picker Engineering Program focuses on developing pedagogy that engages women and under-represented minorities. It is surmised that pedagogy beneficial to these groups is good pedagogy for all. Essential and requisite for the academic preparation of an engineer is a thorough and balanced study of the natural sciences, social sciences and humanities. Our program conducts research in engineering thought, under which is subsumed both the pedagogy of engineering education and the identification and structuring of solutions to the pressing problems (such as sustainability) that face society. Moreover, our work on engineering thought addressed, in the words of the well-known 19th-century scientist Thomas Huxley, 'instruction of the intellect in the laws of nature, under which are included not merely things and their forces, but men [*sic*] and their ways'. The following paper briefly describes

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three of the unique features of the Smith College Picker Engineering Program (PEP): the unity of knowledge approach, improving quantitative literacy, and nurturing entrepreneurship.

### THE UNITY OF KNOWLEDGE

*The greatest enterprise of the mind has always been and always will be the attempted linkage of the sciences and the humanities.* (E. O. Wilson, *Consilience: The Unity of Knowledge*, Alfred A. Knopf, 1998)

Historically, engineering has been taught outside of the context of societal need and impact, rendering the typical engineering education deficient. We, at Smith, define engineering as the application of mathematics and science in service to humanity and as a bridge that connects the sciences to the humanities. With an emphasis on social relevance, sustainability and improvement of the human condition, the Smith Engineering Program will encourage engineers to understand the larger context in which they work. A clear perception of how engineering influences and is influenced by context, society, and even the time in history gives engineers a path for imagining the future. In addition, engineering education placed in social context will develop a more diverse, globally oriented workforce of engineers—a goal highlighted by the National Science Foundation in its Government Performance & Results Act Performance Plan [1].

In an increasingly complex world, there exists a need for an interdisciplinary approach to engineering that includes the expansion of a dialogue that integrates the humanities and the social sciences with engineering. Ultimately, engineering must become an integral part of the liberal arts environment. Increasingly, there is a demand for engineers to participate in interdisciplinary efforts in which the ability to work with team members from other disciplines becomes crucial. This is a subtle skill students must be helped to develop in a world now impacted by fast-paced innovation. The PEP will be dedicated to construction of informed thought supported by a rigorous foundation in engineering that leverages the rich heritage of liberal arts at Smith College. This integrated approach to thought liberates the mind to consider and engage in the great debates that define our times—times that have been driven and permeated by technology.

### QUANTITATIVE LITERACY

*Technology is pervasive in our lives, yet a limited number of people have sufficient quantitative skills or understanding of technology to navigate the most fundamental elements of a technological society and its consequences.*

Technological literacy can be defined as a broad understanding of the human-designed world and

our place in it. It is an essential quality for all people who live in the increasingly technology-driven 21st century. Nearly half a century ago, in his seminal work, *Two Cultures*, C. P. Snow identified a widening gap between the technologic and literary communities. Since that time, little has been done to mitigate this schism. In a time of increasing technological complexity, which touches nearly every aspect of our lives, bridging the two cultures is imperative. As E. D. Hirsch Jr. pointed out in his work, *Cultural Literacy*, literate people in every society and every culture share a body of knowledge that enables them to communicate with each other and make sense of the world around them. The kinds of things a literate person knows will vary from society to society and from era to era, so there is no absolute definition of literacy. In the early 21st century, however, cultural literacy must have a large technological component [2].

To achieve the goal of technologic literacy, first we must address its foundation—quantitative literacy (QL). Just as mastery of vocabulary and grammar is essential to writing, so is quantitative literacy essential to the understanding and application of technology. Quantitative literacy has been described as the ability to understand and use quantitative inferences that allow one to function as a responsible citizen, productive worker, and discerning consumer. Because analyzing and reasoning using data and numbers is ubiquitous in life and in almost all collegiate disciplines, QL is critical for both general education and education in depth. Yet, no discipline claims responsibility for QL education; thus, it has been termed everybody's orphan [3].

We hope to improve QL broadly among Smith Undergraduates by offering courses such as Ancient Inventions, Structures and the Built Environment, Designing the Future: An Introduction to Engineering, and Engineering, the Environment and Sustainability. These courses are designed for general audiences and are designed to 'bridge the gap of the two cultures'.

### ENTREPRENEURSHIP

*Entrepreneurs have been responsible for ninety-five percent of the radical innovations made since World War II [4] while comprising only five percent of the U.S. employers. However, innovative ideas and entrepreneurial endeavors that serve humanitarian needs and the social good often do not attract sufficient funding to bring them to fruition.*

As the capstone of their engineering education, senior students in the Picker Engineering Program will develop a Senior Design Clinic modeled after the Harvey Mudd College senior design experience. Through this clinic, students get hands-on experience solving real-world engineering problems. The senior design project will be the culmination of the students' four years of learning—drawing and

building upon the knowledge gained in the program. Importantly, students will be expected to incorporate knowledge and skills on many levels and crossing many disciplines, including engineering, the sciences (natural and social) and the humanities. The senior design project will be a physical manifestation of the principles and knowledge on which the Picker Engineering Program is built.

The majority of the projects will be funded through agreements with industry sponsors for whom the students solve engineering problems and/or produce a final end-product which is commercially viable. While fulfilling the need of the industry sponsor, Smith recognizes that worthy engineering problems, often with a social or humanitarian purpose, may not attract industry support. The PEP will also act as a springboard for entrepreneurship and innovation in service to humanity. We propose providing seed money and non-monetary types of support for the design and development of select projects.

### EXCLUSIONARY PRACTICES

*The exclusion of women and under-represented minorities in engineering has left us with an untapped resource at a time when we face a severe shortage of engineers.*

Today, two-thirds of the workforce is comprised of women and under-represented minorities. However, these same groups are gravely under-represented in the areas of science, engineering and technology (SET)—the fastest growing sectors in the economy. Currently women represent only 20% of students enrolled in undergraduate engineering programs, 9% of practicing engineers and only 4% of the engineering faculty. Minority groups are similarly under-represented. At a time when we see a growing need for engineers—it is estimated that in the next decade more than 800,000 engineering jobs will be created—the number of people entering the engineering profession is decreasing. To address this imbalance, in its 2000 report [5] the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology identified the need to increase access of these groups to engineering education, to work to retain the same in the engineering disciplines and establish an ongoing system to improve the number and quality of mathematics and science teachers in grades K-12.

As the only engineering program at a women's college in the United States and one of the few within the liberal arts context, the Picker Engineering Program focuses on attracting and retaining women and minorities and preparing them for leadership in quantitative fields. Smith College's

Picker Engineering Program emphasizes unity of knowledge across disciplines and promotes engineering as a liberal art and a profession in service to humanity. The careful design of our curriculum involves a thoughtful process of internal review by both engineering and education faculty so that the required core of courses creates a cohesive and philosophically consistent and connected path to knowledge. This has proven very successful in attracting and retaining women to the program.

A key element to the success of the PEP is the respected and successful Department of Education at Smith College. Within this department, faculty research interests and existing research programs focus on education in the sciences, mathematics and technology. The Engineering Program and the Department of Education are currently collaborating on several projects, laying the groundwork for a long-term partnership where interests and expertise are combined to develop both educators and pedagogy that will redefine engineering education. The research and theory that arise from this collaboration are carried forward into the undergraduate classroom and, importantly, to future and in-service teachers who can broadly disseminate this knowledge at the pre-college level and encourage girls to pursue careers in science and engineering.

### SUMMARY

With only a short history, the Picker Engineering Program has dedicated itself to redefining engineering education. Smith recognized the unique opportunity afforded by developing a program from a 'clean slate'—carefully selecting a high-caliber faculty who are committed to rethinking engineering education to redress the problems entrenched within traditional engineering curricula. The Picker Engineering Program focuses on developing pedagogy to foster engineering thought, which by its very nature requires a unity of knowledge. This novel approach to education in general and engineering education in particular will allow the following:

- development of an exciting, learner-centered curriculum that engages and challenges students;
- development of an integrated curriculum that fosters a mastery of engineering fundamentals within the context of the liberal arts;
- encouragement of socially responsible and sustainability-centered thinking;
- development of a socially and personally relevant curriculum to attract and retain women and under-represented minorities; and
- encouragement to develop the language of technology and quantitative literacy among non-engineering majors.

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**Domenico Grasso** is the Rosemary Bradford Hewlett Professor and Founding Director of the Picker Engineering Program at Smith College. He holds a B.Sc. from Worcester Polytechnic Institute, an M.Sc. from Purdue University and a Ph.D. from the University of Michigan. He is a registered Professional Engineer in the states of Connecticut and Texas. Professor Grasso was Head of Department in Civil & Environmental Engineering at the University of Connecticut prior to joining Smith College and has been a Visiting Scholar at UC Berkeley, a NATO Fellow, and an Invited Technical Expert to the United Nations Industrial Development Organization in Vienna, Austria. Professor Grasso is currently Vice-Chair of the Environmental Engineering Committee of the EPA Science Advisory Board, past President of the Association of Environmental Engineering Committee of the EPA Science Advisory Board, Editor-in-Chief of *Environmental Engineering Science*, and Associate Editor of *Reviews in Environmental Science and Biotechnology*. He recently chaired a US Congressional briefing entitled 'Genomes & Nanotechnology: The Future of Environmental Research'. In 2000, The Water Environment Federation named him a 'Pioneer in Disinfection'. In 1998, Professor Grasso served on a World Bank funded international team of scholars that established the first environmental engineering program in Argentina.

**Kara Callahan** is the Assistant to the Director of the Picker Engineering Program at Smith College. She holds her undergraduate degree in mathematics from Smith College and Master's degrees in Civil and Environmental Engineering and Technology and Policy from MIT. Prior to joining Smith College in her current position, Ms Callahan spent thirteen years in the energy industry. She has significant experience in developing complex energy forecasting models that integrate financial and operational data from generation, transmission and retail power units used for strategic planning and analysis. Ms Callahan has worked extensively in the UK, the US and African markets, where she developed models for analysis of asset valuation, power markets, retail electricity pricing and environmental impact. Prior to her work in the power industry, she worked as a research assistant at the Volpe National Transportation Center. In that role, she developed a multiple source emission model to forecast greenhouse gas emissions from the transportation sector.

**Sandra L. Doucett** is Senior Director of Corporate and Foundation Relations at Smith College. She has been a member of the Advancement staff at the College since 1989. A graduate of the University of Massachusetts, Amherst, Sandra has attended the Smith College Executive Education Program and the Cornell University Strategic Management Program. She is a member of the Smith College Science Planning Committee, the Science Center Building Committee, and the Smith College United Way Steering Committee. She devotes a large proportion of her time to raising funds and building corporate relationships for the new Picker Engineering Program.