

# Forewords

This book addresses a major issue of our times. As knowledge has inexorably grown over the years it has become ever more compartmentalized, and nowhere is this truer than in engineering. Engineering has for more than a century been divided into subfields such as electrical, civil, mechanical, and chemical, and now it has become specialized within those fields. Engineering education is nearly entirely scientific and technical. It leaves little room, if any, for learning other areas.

By contrast, actual engineering challenges are more and more multidimensional and are not solely technical in nature. Many engineering issues interact so closely with society and the public sector that they cannot be addressed without full recognition of the social and political dimensions. Examples abound, some of them being energy supply, conversion, and storage; clean water and water conservation; mitigation of pollution of air, land, and water; health care for the world's have-nots; global warming; and harvesting the potential of biotechnology for agriculture, food, and medicines. Many of these issues are so complex that they must be addressed by teams composed of persons versed in a variety of disciplines, with each member being cognizant of the concepts and approaches of the other team members. With globalization of business and society, engineering has become a worldwide profession, requiring good understanding of others' cultures and circumstances. The highly technical and narrow aspects of engineering education have served to limit the population to whom it is attractive. The need for major change in engineering education is urgent.

Domenico Grasso and Melody Brown Burkins have assembled an impressive array of authors from diverse backgrounds to explore the present-day circumstances and needs for engineering education and practice. The ideas and arguments put forward show that, while there is much agreement on the directions of change that are needed, there are still diverse opinions on the specifics. But it is clear that engineering education must be placed on a much wider base of knowledge, must integrate concepts of practice and social needs and impacts with the underlying scientific base, and must provide entry and exit points as education proceeds, rather than implicitly requiring a pre-college career decision. Koshland and Christ, in their essays, are convincing with regard to the value of an underlying liberal education for engineers.

With support and impetus from such leaders, why is change not happening faster? First of all, the traditional undergraduate engineering curriculum is chock full, in fact overstuffed. Thus broadening requires either taking technical material out or moving the professional degree to the graduate level, as is already the case for all other major professions. Therefore, in order to do the job right, not only must there be major broadening but there must also be an accompanying change in degree structure. There are, however, large sources of resistance and inertia. Although many corporate leaders appreciate the needs for broadening and some have explicitly urged movement of the professional degree to the graduate level, industrial recruiters by and large look toward the needs of the initial job function. They are largely satisfied with the present bachelor's engineering graduate and welcome not having to provide the higher salaries that are usually associated with further education. University faculty members have large and interacting burdens of teaching, research, and service. Changes in curriculum and degree structure are added burdens. Many faculty members concentrate upon the technical material that they know best and do not yet see the need for breadth. Professional societies reflect the interests of their industrial and academic members. Breadth serves the career interests of the students, but they are not yet well aware of that and are not much at the table anyhow for determining the curriculum. Breadth also promotes innovation and competitiveness, which are major public benefits, but the public is only very indirectly at the table. Of course, there are important islands where change is happening, but the large movements have yet to occur.

If readers of this volume are convinced that much broader, holistic engineering education must become the norm, what can they do to help it along? Change can and will happen when corporate leaders pass their own recognition of these needs down to the front line of the corporation. It will happen when professional societies and groups such as the National Academy of Engineering succeed in providing convincing arguments to university leaders and accreditors of universities. It will happen when would-be engineering students, their families, and donors of financial aid recognize that the additional expense of a broader education is both a sound investment and intellectually rewarding. It will happen when engineering faculty recognize that the multidimensionality of today's and tomorrow's challenges demand much more breadth than can be packed into the curriculum at the baccalaureate level. It will happen when engineering as a profession recognizes the wisdom that drove medicine, law, business, architecture, pharmacy, and other professions to build graduate-level professional education on the base of a liberal undergraduate education.

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A little more than 10 years ago I became the first employee of the Franklin W. Olin College of Engineering. Olin College was created specifically to address the need for systemic change in undergraduate engineering education. As a result, my colleagues and I have spent much of the last decade thinking almost exclusively about the subject of this book. This naturally involved thinking hard about the challenges of the future and also about the nature of engineering.

Taking a broad historical perspective, technology through the ages appears to serve as a form of “amplifier” of human intentions. It enables a smaller and smaller number of people in each succeeding generation to affect the lives of larger and larger numbers of others in society. These effects may be beneficial, or they may not. They may be intentional, or they may be unintentional.

Some years ago the National Academy of Engineering developed a list of the greatest technological achievements of the 20th century. The list included many things that we take for granted today, including electrification, the automobile, the airplane, clean drinking water, the telephone, computers, and the internet. The list is all about things—things that have transformed life on the planet. However, recently the Academy published a new list of 14 grand challenges for the 21st century. This new list is characteristic of a broad set of challenges that transcend time zones and political boundaries, including global climate change, sustainable energy, security in an age of terrorism, affordable quality health care. To a much greater extent than the achievements of the last century, these new challenges will require a holistic, systems approach to intentional engineering design that embraces the need to include human behavior on a global scale. It is clear that leaders for these new global challenges will require a much greater level of understanding of non-technical issues surrounding technological invention in order to avoid unintended consequences. The unintended consequences of previous technologies have, in some cases, contributed to the grand challenges we face today. These unintended consequences must be given substantially more attention now in order to achieve overall outcomes that are required, not just new technologies. These consequences often have to do with human behavior, and require primary consideration of economic, political, social, psychological, and even religious dimensions of the introduction of new products and systems.

The many distinguished authors in this important book provide many different perspectives on the challenges we face and the educational paradigms we are using today to produce the engineering leaders for the future. While each of them presents a different perspective, the theme of the book is clear: engineering leaders for the 21st century will need a much broader perspective and a holistic, systems-oriented education that is not common today. Change is needed, and the chorus of voices here makes a compelling case that the time has arrived. It will take a coordinated effort across many institutions to accomplish the change, and the change will undoubtedly take different forms in different institutions. But the basic compass direction for change is becoming clear. Deeper and deeper specialization in narrower and narrower engineering sciences is not the answer. We need a fresh approach, perhaps a new definition of engineering itself. Perhaps engineering has more to do with a way of looking at the world than with mastery of applied science and

mathematics. Perhaps engineering is a method involving imagination, experimentation, and iterative improvement – a method that is not as common in our educational programs as it could be – a method that shares many of the basic principles of design or even fine arts. Perhaps engineering and entrepreneurship are so closely inter-related that they are at times indistinguishable, and involve seeing opportunities rather than problems, taking initiative and risk, and – through sustained effort – making a positive difference in the world. Perhaps engineering involves—as James Plummer of Stanford University has noted – the intersection of feasibility, viability, and desirability. It is not simply a matter of feasibility any more.

The ideas and opinions presented in this book provide a call for change, and also provide a clear direction for the change that is needed. I believe the message is important, timely, and compelling, and I am grateful to the authors for their vision, passion, and dedication to this important cause. The focus on developing holistic and systems approaches to the practice of engineering is exactly what is needed, in my opinion.

However, as we progress from here and the profession continues to evolve, I would like to suggest that we look beyond our peers in the field of engineering for models of change. There is an enormous amount of “low hanging fruit” to be obtained from close observation of the most effective innovations in business education and in medical education (and I am sure there are others). I would urge all readers of this volume to reach out to our peers in the other professions and in the arts and sciences and widen our observations and our conversations to build a truly holistic approach to change in the process of education. Changing the educational process may prove to be one of our grandest challenges and there is much to be learned from those in other fields.

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A holistic approach to engineering education is not a new concept at Harvey Mudd College. From its founding in 1955, HMC's approach to both engineering and science education has been one requiring breadth and depth across science, engineering, mathematics, social sciences and humanities, as well as cross-disciplinary integration via a systems approach. HMC's engineering degree has always been a general engineering degree, and HMC sees itself as a liberal arts college of science and engineering. Thus is a joy to see a book in which so many leaders from engineering education and practice endorse the ideas at the core of the Harvey Mudd College mission.

Even with more than 50 years of experience attempting to get holistic engineering right, together with the knowledge from our partners at other institutions with similar goals, e.g., Princeton, Smith, Swarthmore, Olin, and UVM, there is still much to learn. Moreover the rapid changes over the last decade in the global economy, the increasing concerns about energy and environmental issues, and the ongoing transformation of every aspect of society by information technology place new demands on engineering education. Today, every undergraduate engineering student should gain some international experience, understand the implications of energy generation and consumption and be highly proficient with computational tools. This is in addition to the superb skills we expect in leadership, communication, and teamwork as well as technical breadth and depth, and commitment to professional ethics.

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