

What Does It Mean to Think Like an Engineer—Today?

by

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Executive Summary. Engineers, like other professionals, are expected to perform specialized tasks in society—not simply behave as passive citizens with special knowledge. Often, public safety and welfare depend on their professional performance. As we race into the 21st century, the rate of growth of important new science and technology is accelerating, while the complexity and scope of global challenges requiring engineering expertise are also rapidly expanding. However, the time available to educate an engineer is not. Educators everywhere face constant and intense pressure to decide what to include in a modern engineering education and what to leave out. Other professions, such as medicine and law, face similar challenges as a result of similar expansion in critical new knowledge, such as the human genome project, rapid changes in the law, and ascension of global Grand Challenges such as sustainability, security, and accessibility of quality healthcare. In some ways, the contents of a professional education are analogous to the contents of a backpack that must sustain a hiker on a 40+ year journey through uncharted territory. It is not feasible to simply add endlessly to the contents. Critical decisions must be made in deciding what content to pack and what capabilities, skills, and motivations to include within the fixed time available. One approach to this challenge is to focus on the essence of the professional function of an engineer in the 21st century. Reaching some shared vision of what it may mean to “think” like an engineer can provide useful guidance to all engineering educators. This short paper attempts to explore what several key individuals with diverse backgrounds and experience think about the evolving identity of engineering and the trends in education that might bear on this important question.

Recent Trends in Engineering and Education. Education is a process of learning not what to think but how to think. Different disciplines have differing methods and modes of interpreting, thinking, and doing. Engineering education has often been viewed as imparting a powerful method of thinking that has traditionally commanded a premium in the marketplace. However, as with many professions and academic disciplines, what it means to be an engineer continues to evolve.

The engineering profession has recently attempted to better align its programs with the Grand Challenges of the 21st century. These challenges were recently outlined in a report by the National Academy of Engineering³. One of the consequences of this realignment is the enhanced perception of the relevance of the field of engineering by current and prospective students and by the public at large.

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³ <http://www.engineeringchallenges.org/cms/challenges.aspx>.

In a recent conversation with Dr. Ian Waitz⁴, he reported that at MIT, both students and faculty today are increasingly attracted to Grand Challenge problems that are complex and interdisciplinary and highly relevant to society, while they are becoming less interested in traditional disciplines, like mechanical engineering and electrical engineering. He said that MIT students today may arrive with a passion to study sustainable energy and ask for advice on which courses to take.

The relatively recent and highly regarded report, Educating the Engineer of 2020⁵, attempted to identify new key competencies of engineers that will be required by 2020 to address the Grand Challenges. In particular, this report suggested that technical preparation will not be sufficient to address the complex global problems ahead, and that a modern engineering education must do a better job of preparing graduates to work well in multidisciplinary teams, act as leaders, think creatively and entrepreneurially, and to integrate broad social and societal perspectives into engineering designs. Although many of the recommendations in the report pointed to an engineering preparation that is significantly different from the traditional education offered in recent decades, Dr. David C. Munson, Jr.⁶, recently noted that, "Educating the Engineer of 2020 was not necessarily as revolutionary as some people may think. Many schools were hard at work, making the types of important changes called for in the report's recommendations." Olin has certainly attempted to lead in this effort among engineering schools.

In this white paper, we present some provocative, erstwhile and futuristic perspectives of what it means to think like an engineer in the 21st century. What does this encompass? Are American universities preparing students to "think like engineers?" If so, are they focused on the engineering skills of the 21st century or are they stuck in the 20th century? If they are attempting to address the future, is the pace or change adequate?

Lessons from Law and Medicine. At the end of the 1800s, law schools concluded that there were too many laws to continue to try to teach all the laws. Rather, they moved to teaching students how to "think like lawyers" (a common refrain heard at law schools around the nation). In engineering, certainly, technology is arguably moving even faster than vicissitudes of the law; we can no longer teach all the science and technology that engineers need to know, even on their first day on the job (hence the need for life-long learning). However, we as a profession have not been entirely explicit about what it means to "*think like an engineer.*"

Dr. Elizabeth G. Armstrong⁷ helped lead a transformation of medical education at Harvard Medical School in the 1980s and '90s. The New Pathway⁸ curriculum introduced there completely changed the paradigm from intense lecture courses in basic sciences in the early years, to an aggressively problem-based curriculum. She sees engineers as professionals similar to physicians and attorneys that "*must have certain characteristics.*"

⁴ Dean of the School of Engineering and Jerome C. Hunsaker Professor of Aeronautics and Astronautics at MIT and member of the President's Council at Olin College.

⁵ Educating the Engineer of 2020: Adapting Engineering Education to the New Century, National Academy of Engineering, Washington, DC (2005).

⁶ Robert J. Vlasic Dean of Engineering and Professor of Electrical Engineering and Computer Science at the University of Michigan.

⁷ Director of the Harvard-Macy Institute and Clinical Professor of Pediatrics at Harvard Medical School, and Trustee at Olin College.

⁸ Tosteson, D.C., Adelstein, S.J., and Carver, S.T., New Pathways to Medical Education: Learning to Learn at Harvard Medical School, Cambridge, MA: Harvard University Press, 1994.

For example, a professional—no matter the discipline—is a person who continues to learn and constantly moves the field forward. To be competent, a professional must have a solid foundation in the disciplines of the field—like math and science for engineers. However, the professional must always go beyond the knowledge base, and ask fundamental questions to challenge the status quo and advance the field. So above all, young engineers should be prepared to ask good questions.”

“A professional MUST be a ‘systems thinker’—embrace the entire context of the problem—Engineers have a special responsibility here—this involves understanding feedback loops and processes for improvement, the nature of interactions between components in the system, etc. We must prepare them to build a systems framework for problems.” Charles Fadel⁹, in relating this concept specifically to the engineering profession, “to think like an engineer begins with ‘systems thinking.’ This involves several things, such as seeing the big picture in a comprehensive sort of way.”

He continues by noting that, in contrast to other kinds of leaders who think in terms of systems (e.g., policy makers and politicians, etc.), *“what really sets engineers apart is their insistence on going the next step and building a prototype or detailed simulation to test and see if the system works. All successful man-made processes must involve this kind of engineering thinking, whether it is explicitly recognized, or not.”*

But are the responsibilities of engineers in the 21st century limited to technical aspects of the systems they design? How is the technology that is designed and built by engineers contextualized in societal and human systems where engineers have often had little formal exposure and training? What is the role of the engineer in problem definition as well as problem solving? What are the differences between thinking like a scientist and an engineer? We certainly do occasionally model for our students how to think like engineers, but we are not always transparent or explicit about it. If we, as a profession, could be clearer in this definition, it could really help support a more holistic educational framework. ABET has identified the essence, or core competencies, of what is expected from an engineering education:

ABET Outcomes

- a. Ability to apply mathematics, science and engineering principles.
- b. Ability to design and conduct experiments, analyze and interpret data.
- c. Ability to design a system, component, or process to meet desired needs.
- d. Ability to function on multidisciplinary teams.
- e. Ability to identify, formulate and solve engineering problems.
- f. Understanding of professional and ethical responsibility.
- g. Ability to communicate effectively.
- h. The broad education necessary to understand the impact of engineering solutions in a global and societal context.
- i. Recognition of the need for and an ability to engage in life-long learning.
- j. Knowledge of contemporary issues.
- k. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

⁹ Co-author of the best-selling book 21st Century Skills, former Global Education Lead at Cisco Systems, global education thought leader and member of the President’s Council at Olin College.

Without question, these are all valuable assets and capabilities, albeit a bit less succinct than what it means to think like a lawyer.

For example, according to Marc Mihaly¹⁰, *“what it means to think like a lawyer is learning how to listen with empathy to both the spoken narrative and the unspoken subtext, then emptying your head of suppositions and absorbing views on all sides. It means internalizing and feeling comfortable that there are so rarely simply right answers, but rather many perspectives, most of which have validity. This is a precursor to learning to advocate with equal power for different actors in a conflict. Lawyers are also trained to listen to a story, that is, a client’s presentation of a problem, and then disaggregate the narrative into elements, determine the pivotal legal and policy issues, and craft a solution.”* Similarly, Dr. John J. Tracy¹¹ sees that *“at the heart of good engineering practice is the ability to listen well, observe closely, and diagnose the real heart of the problem, identify what it is that is important, and discard the things that are not important. It also requires the ability to cope with differences of opinion successfully.”*

Mihaly suggests that *“good lawyers know that life in an advanced post-industrial society is complicated, and in life we tend to get involved in situations where we embody that complexity. That’s why many people don’t like lawyers because they have a need to believe that life is simple. It’s not, of course, and we end up carrying that reality.”*

But he continues, *“learning to be a lawyer in the 21st century will require broadened skill sets. We need to teach lawyers to think like engineers, economists, planners, etc. Disciplines need to be rethought; silos are dead in the world.”*

“The most imaginative people are multi-professional.”

View from Engineering Practice. That the future demands a different preparation than the past is a sentiment not confined to Mihaly’s or the legal profession’s viewpoint. Dr. Joseph Helble¹² noted that *“21st century engineers must be open minded about solutions. There are many technology-based solutions but some solutions may not be totally technology based. Engineers must imagine all possible solutions. It is about ‘means thinking’ not just calculating.”*

Helble goes on to explain, *“the straightforward types of calculations that had been the bread and butter for many engineers can now be done in many cases overseas at lower costs. Rather than focusing on rote calculations, US engineers have the opportunity to differentiate themselves and generate added value by focusing more on the interdisciplinary and creative aspects of problems and challenges. They will become more ‘whole systems’ thinkers and innovators. This will give them much greater opportunity in the job market, which is important if it becomes increasingly difficult to find traditional engineering jobs geared towards traditional engineering degrees.”*

Sherwin Greenblatt¹³ shares this opinion: *“Rather than attempting to learn all the newest methods and advanced techniques of analysis, engineering education should focus on*

¹⁰ President, Dean and Professor of Law at the Vermont Law School.

¹¹ Chief Technology Officer and Senior Vice President of Engineering, Operations and Technology at The Boeing Company and member of the President’s Council at Olin College.

¹² Dean of the Thayer School of Engineering and Professor of Engineering at Dartmouth College.

¹³ Former President and CEO of Bose Corporation and Trustee at Olin College.

three basic skills: (1) learning how to “frame” problems well; (2) learning how to find appropriate modern techniques for solving a problem; and (3) learning how to learn how to apply these techniques to obtain useful solutions. New subjects and techniques will continue to arise, and some awareness of these is important. But not more important than the basic skills that define thinking like an engineer.” The pace of technological advance is increasing so fast, we must be able to learn quickly and independently. Tracy adds to Greenblatt’s comments identifying “*adaptability as important as anything else on the list.*”

Helble notes that “*what Olin is doing is spot on—open ended, creative, ‘needs finding’ – that also capitalizes on liberal arts.*” Unfortunately, Fadel observes that nationally, “*too often today, engineering schools only give lip service to teaching the ‘soft skills’ that derive from an understanding of the humanities and social sciences. Most of the engineering faculty today did not have much exposure to these fields and they have less respect for them. In addition, the admission process seems to ‘down select’ for incoming students that also have little interest in these subjects.*” Helble continues, “*being able to step back and appreciate all solutions, not just the technical. A good example of this is our transportation system, which goes well beyond engineering to include many other disciplines.*”

An example of the complex problems referred to by Helble is the Stockholm transportation system¹⁴. When Stockholm was considering ways to transport more people into and out of the city, the concept of adding one more bridge to the 57 that already connect the 14 main islands that constitute the city would have been the natural engineering extension of past practices. However, Stockholm retained IBM—a company with a very large number of engineers. But IBM, prompted by an economic realignment in the United States from manufacturing and industry to services and innovation management, has already moved beyond traditional engineering thinking to a much broader domain. Specifically, the company has embarked on a research-and-business model that applies technological and manufacturing models to the holistic delivery of services.

To solve Stockholm's traffic problem, IBM designed a "tax and drive" system, in which autos are fitted with transponders and drivers are charged a fee, based on the time of day their cars are in the city. In the first month of operation, the system yielded a 25-percent reduction in traffic, removing 100,000 vehicles from the roads during peak business hours and increasing the use of mass transit by 40,000 riders per day. Stockholm needed no new bridge and gained the concomitant benefits of reducing pollution and conserving energy.

Even in a state that has been dominated by a traditional transportation engineering paradigm, Munson noted that “*even in traditional industries, such as automotive, it's not about rote training. Everyone is looking for creative engineers.*”

He goes on to note that engineering students’ education is not limited to the traditional curriculum, since acquisition of creative, innovative, and multi-disciplinary skills are encouraged in less formal ways. “*Much of an engineering student's education should happen outside the classroom. At Michigan, students are heavily involved in entrepreneurship, multidisciplinary design projects, the arts, 1400 student groups and societies (providing leadership experience), and international programs (international engineering is our most popular minor, despite requiring serious study of foreign language).*” Engineering education on a large university campus depends in important

¹⁴ Grasso, D. and Martinelli, D, “Holistic Engineering,” *Chronicle of Higher Education*, 16 March 2007.

ways on the learning ecology provided by interactions with students in other disciplines in the residence halls, clubs, and student-initiated projects.

This is especially important because as Munson notes *"engineering graduates may do highly technical work for only five or six years after graduation, so business and softer skills (including teamwork and communications) become more important. These can be taught in a matrix of educational experiences, so that softer skills are built into engineering classes."*

Mark Papermaster¹⁵ agrees with Munson that understanding basic principles of natural science and applied mathematics are as important today as they have ever been. But Papermaster underscores that *"as important as this competency in fundamentals of science and math is, it is no longer enough. Today, it is critically important that young engineers also develop a high level of competency in communicating across disciplines and working on problems with others on small multidisciplinary teams. New engineers must learn to work comfortably with others whose expertise is very different from their own. If they learn how to collaborate well, they can both teach and learn new concepts and methods from others for the rest of their career, developing new frontiers and products."*

Similarly, Greenblatt sees *"the hallmark of an Engineer as solid understanding of first principles of natural science and math and the ability to approach problems from a comprehensive 'systems' perspective. Good engineers always have a good qualitative understanding of the overall process, from a 'flow chart' and causality point of view. Of course, quantitative reasoning and analysis are important, starting with estimation and common sense. Focusing on advanced methods of analysis only makes sense after acquiring a degree of common sense in framing and solving problems."*

Summary and Conclusions. These comments from some of the nation's thought-leaders clearly point to the need for a holistic skill set for engineering students. These skills can be acquired in and out of the classroom and require a balance of the traditional quantitative corpus traditionally associated with engineers as well as a broader set of skills more commonly associated with business and liberal arts education. The ABET outcomes summarized earlier, by and large, reflect the essence of many of the remarks of the individuals interviewed for this paper regarding what it means to think like an engineer.

All of those interviewed agreed that understanding the fundamentals of natural science and math will remain central to the knowledge base of engineering for the foreseeable future. However, in addition, developing the ability to frame complex problems with a comprehensive systems approach and include non-technical dimensions in the framing and the potential design and solution space are equally important. Furthermore, since creative solutions almost always emerge from multidisciplinary teams (rather than the solo work of an individual), the ability to effectively collaborate with team members from disciplines outside engineering and to build predictive models and prototypes to verify the performance of new designs are fundamental to thinking like an engineer. To provide more background and context on these conclusions, a complete summary of all the interview comments will be made available as a separate document.

¹⁵ Chief Technology Officer at AMD Corporation and member of the President's Council at Olin College.

Furthermore, to help focus our discussion at the meeting, we will consider together the following questions:

1. How do you think the practice of engineering will change in the 21st century, and why? (What forces are at work? What trends do you see?)
2. What new abilities will engineers need in order to excel in this new role? What current abilities—if any—do you believe will become less important in the 21st century?
3. What do you think it means to “think like an engineer”?

Summary of Interviews
on
What Does It Mean to Think Like an Engineer—Today?



Elizabeth G. Armstrong

*Director of the Harvard-Macy Institute and Clinical Professor of Pediatrics
Harvard Medical School*

“What does it mean to think like an engineer? I think of engineers as an example of a ‘professional’ and in that context, I think professionals must have certain characteristics. For example, a professional—no matter the discipline—is a person who continues to learn and constantly moves the field forward. To be competent, a professional must have a solid foundation in the disciplines of the field—like math and science for engineers. However, the professional must always go beyond the knowledge base, and ask fundamental questions to challenge the status quo and advance the field. So above all, young engineers should be prepared to ask good questions.

A professional MUST be a ‘systems thinker’—embrace the entire context of the problem—Engineers have a special responsibility here—this involves understanding feedback loops and processes for improvement, the nature of interactions between components in the system, etc. We must prepare them to build a systems framework for problems. (In comparison, in medicine, there is profound lack of understanding of systems thinking, for example when it applies to organizations and the health care system.) In addition, a professional must be committed to lifelong learning. Professional fields are not static—they constantly evolve and spawn new knowledge and disciplines.

Beyond a fixed set of competencies, a professional should be able to create the innovations that move the field forward. An outline for how to do this is provided by Gregersen, Dyer and Christensen’s book on The Innovator’s DNA. In particular, these five characteristics include: observing, questioning, associating, networking, and experimenting. He claims that these characteristics are all teachable.”



Charles Fadel *

Co-author of the best-selling book 21st Century Skills, former Global Education Lead at Cisco Systems and global education thought leader

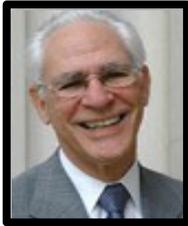
“Today, we need to find ways to spread “engineering thinking” to many others outside the engineering community. To think like an engineer begins with ‘systems thinking.’ This involves several things, such as seeing the big picture in a comprehensive sort of way. For example, imagining a kind of ‘flow chart’ that identifies the flow and causality of information and actions, including feedback loops and opportunities for adaptation and correction. However, while some – actually, few! - others in society also apply this kind of qualitative ‘systems thinking,’ what really sets engineers apart is their insistence on going the next step and building a prototype or detailed simulation to test and see if the system works. All successful man-made processes must involve this kind of engineering thinking, whether it is explicitly recognized, or not.

Regarding what and how to teach young engineers today, all the advice in the NAE monograph *Educating the Engineer of 2020* are on target. However, too often today, engineering schools only give lip service to teaching the ‘soft skills’ that derive from an understanding of the humanities and social sciences. Most of the engineering faculty today did not have much exposure to these fields and they have less respect for them. In addition, the admission process seems to ‘down select’ for incoming students that also have little interest in these subjects and share a very similar personality profile.

Another important characteristic to develop in engineers is strong synthesizing skills—the ability to go beyond deep analysis as a mode of thinking. For generations now, we have emphasized and trained engineers to become specialists in deep analysis, with an intense focus on details and calculations. However, to become creative engineers, they must later learn to switch off this mode of thinking to become proficient in synthetic thinking, which is made particularly difficult because of this early emphasis (“you are what you train”). And importantly, they need to know when enough is enough, when optimization gets in the way of efficiency, for instance.

The education of future engineers in ‘design thinking’ is essential. In particular, they need to learn the difference between incremental innovation and radical innovation. The methods of artificial intelligence are providing methods of exploiting patterns in design evolution to systematize incremental innovation. So radical innovation will therefore become even more important for engineers, coupled with their ability to master A.I. tools (A.I. should be a mandatory element of any engineering curriculum).

The complete engineer of the future should develop a number of meta-competencies to complement the professional skills. These include learning how to teach others how to think like an engineer, developing a degree of self-awareness to enable personal and professional growth in ways that compensate for personal weaknesses and strengths (and those in the team around you), and developing a degree of wisdom to know when you should not do/create something just because you can .”



Sherwin Greenblatt

Former President and CEO, Bose Corporation

“The hallmark of an Engineer is a solid understanding of first principles of natural science and math and the ability to approach problems from a comprehensive “systems” perspective. Good engineers always have a good qualitative understanding of the overall process, from a “flow chart” and causality point of view. Of course, quantitative reasoning and analysis are important, starting with estimation and common sense. Focusing on advanced methods of analysis only makes sense after acquiring a degree of common sense in framing and solving problems.

Rather than attempting to learn all the newest methods and advanced techniques of analysis, engineering education should focus on three basic skills: (1) learning how to “frame” problems well; (2) learning how to find appropriate modern techniques for solving a problem; and (3) learning how to learn how to apply these techniques to obtain useful solutions. New subjects and techniques will continue to arise, and some awareness of these is important. But not more important than the basic skills that define thinking like an engineer.”



Joseph J. Helble

*Dean, Thayer School of Engineering and Professor of Engineering,
Dartmouth College*

“The straightforward types of calculations that had been the bread and butter for engineers are now done overseas at lower costs. Rather than focusing on rote calculations, US engineers have the opportunity to differentiate themselves and generate added value by focusing more on the interdisciplinary and creative aspects of problems and challenges. They will become more whole systems thinkers and integrators. It may become increasingly difficult to find jobs with traditional engineering degrees.

What Olin is doing is Spot on - open ended, creative, needs finding – that also capitalizes on liberal arts.

Being able to step back and appreciate all solutions, not just the technical. A good example of this is our transportation system, which goes well beyond engineering to include many other disciplines.

21st century engineers must be open minded about solutions.

There are many technology-based solutions but some solutions may not be totally technology based. Engineers must imagine all possible solutions. It is about means thinking not just calculating.”



Marc B. Mihaly

President and Dean, Vermont Law School

“What it means to think like a lawyer will vary depending with whom you are speaking. From my perspective, it means emptying your head of suppositions and absorbing best views on both sides. Feeling comfortable that there are no right answers and learning to advocate on one side and then another side and then another. Listen to a story – disaggregate story and turn it into a solution. Most lawyers would say it is the analytic skills set that teaches you to argue both sides of an issue.

Many people don't like lawyers want to see life as simple. Good lawyers know that it is complicated require sometimes complicate systems to be created.

Learning to be a lawyer in the 21st century will require broadened skill sets. We need to teach them to think like engineers, economists, planners, etc. Disciplines need to be rethought they are silos; silos are dead in the world.

The most imaginative people are multi-professional.

On the legal side Professors rooted in present and cannot think about the future. They think that the future is like the past. It is like Borders not worrying about computers. The future is about market innovation, and automation. This will create a new paradigm.

We need to be able to teach beginning knowledge intermediate knowledge advanced knowledge that will be needed by practitioners – a sort of curriculum mapping.”



David C. Munson, Jr.

Robert J. Vlasic Dean of Engineering and Professor of Electrical Engineering and Computer Science, University of Michigan

“The Engineer of 2020 was not necessarily a revolutionary report. Many schools have been at work trying to implement these recommendations.

Much of engineers' education happens outside of the engineering classroom, giving them multidimensional perspectives. Examples of activities that happen outside the traditional academic structure include entrepreneurial activities, international projects (at Michigan foreign languages are the most popular engineering minors, even more so than math), multidisciplinary design projects.

Engineering graduates do technical work for only five to six years after graduation so business and softer skills (including team work and communication are needed. These can be taught in a matrix of educational experience so softer skills are built into engineering classes.

Much of engineering is tied to the environment and sustainability. Everyone needs a life-cycle type of course to understand ultimate implications.

It is not just about rote training; even auto industry looking for creative engineers not looking for the standard engineers.”



Mark Papermaster *

Chief Technology Officer, AMD Corporation

“In thinking about what is important for all young engineers to know today, two fundamentals stand out. The basic principles of natural science and applied mathematics are as important today as they have ever been, and to be successful, all new engineers must continue to have a solid understanding of these fundamentals. However, as important as this competency in fundamentals of science and math is, it is no longer enough. Today, it is critically important that young engineers also develop a high level of competency in communicating across disciplines and working on problems with others on small multidisciplinary teams. New engineers must learn to work comfortably with others whose expertise is very different from their own. If they learn how to collaborate well they can both teach and learn new concepts and methods from others for the rest of their career, developing new frontiers and products.”



John J. Tracy *

Chief Technology Officer and Senior Vice President of Engineering, Operations and Technology, The Boeing Company

“At the heart of good engineering practice is the ability to listen well, observe closely, and determine the basic cause of the problem or the kernel of the customer requirement. It is critical to identify what is important, and not be distracted by the rest. This is another way of saying that good engineers are always good at framing the problem correctly. They have an accurate view of what is important and they are able to break problems down into their constituent parts through applying first principles to derive a basic understanding.

Regarding the content of a good engineering education, it is likely to remain math and science based for the foreseeable future. A solid understanding of the first principles will always be important. However, the specialized tools—and possibly even the disciplines we recognize today (mechanical engineering, electrical engineering, etc.) are likely to evolve significantly in the future. So, the emphasis should be on basic principles from which you can later learn the latest new special topics on your own.

At Boeing, engineering projects always involve teams. In order for engineering graduates to excel in this environment, it is essential that they learn to work well on teams. This requires the ability to listen well, communicate ideas—even in the face of disagreement and conflict, and collaborate with others from different fields and backgrounds. Diversity is an important ingredient in successful teams because it opens the design space to a much broader range of solutions through the inputs of people with many different points of view. Ethics and integrity are also critical, because our work impacts the safety and wellbeing of many people. Our engineers can never take short cuts. They must always face the cold, hard facts, with no excuses or shortcuts since passenger safety can be compromised. Finally, engineers today must learn to be adaptable, since the technologies and sometimes even the science they will need hasn't been invented yet.

I also want to report a concern that I have. I am worried that some new engineering graduates do not seem to have a real desire to become technically excellent at something at the start of their career. Instead, some seem to be immediately interested in becoming the CEO or the leader before they have developed mastery over any particular field. I believe that engineering education should stress the need to develop deep competence in an area or two before broadening out and moving into major leadership positions.”

* Member, Olin College President's Council