Are We Attracting the Right People into Engineering?

by

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Executive Summary. The percentage of American high school graduates who are both interested in and prepared for the study of engineering continues its general decline. Those who are both interested and prepared are largely Caucasian males, a declining fraction of our population. On the other hand, the National Academy of Engineering (NAE) has identified a broadened set of competencies that will be required of successful engineers in the 21st century, with emphasis on communication skills, teamwork, leadership, creativity, entrepreneurial thinking, and other attributes. The public understanding of engineering is poor, and concern about outsourcing of technical jobs has caused some hesitation among students to consider the engineering field. Meanwhile, admission procedures at many engineering schools continue to emphasize grades and test scores in math and science. The result is widespread concern about the ability of the U.S. to produce the next generation of innovators who can predict, create, and manage the technologies that will shape our future. This brief paper goes beyond the question of sheer numbers and focuses on the broadening of the competencies that are called for. It raises the question, "*are we attracting the right people into engineering*?" It proposes a major shift in thinking about the entire admission process, ranging from the definition of engineering, the role of students in their education, the criteria for selection, and the process of recruitment. Few things are more important to the profession than attracting the right people in the first place. The paper ends by raising several questions for discussion after the reader has personally observed the activities of a "Candidates' Weekend" at Olin College.

Background. In recent years the media and government in the U.S. has become more concerned about the need for technological innovation. A well known recent book by Thomas Friedman[1] is one of several that emphasize the changing world economy and the important role that technological innovation will play in the future of the U.S. Friedman emphasizes the need for improvement in math and science education at all levels, and in investments in funding for fundamental research, among other things. Some people are concerned about the economic competitiveness of the U.S. in the face of rapidly rising economies in Asia, India, Europe, South America and elsewhere. They feel that a strong U.S. engineering workforce is needed to lead the U.S. economy through technological innovation. Other people are worried about the increasing complexity of the global challenges that will affect all nations, including climate change, sustainable energy, affordable quality healthcare, etc. These new challenges require integrative knowledge of both technical and social advances. In addition, they also require creativity and innovative thinking across disciplines along with entrepreneurial motivation and global teamwork. But engineering competence remains central to both of these issues. Engineers will be required to drive the competitiveness of the U.S. economy in the future, and engineering competence is also central to many of the global challenges we face.

Where will these integrative, innovative, entrepreneurial engineers come from? The large majority of engineers in the U.S. workforce have B.S. degrees from U.S. colleges and universities. Since only a small fraction of undergraduates in engineering in the U.S. are from abroad, our engineers will come largely from the U.S. K-12 educational system. Unfortunately, many studies have shown that K-12 educational programs in the U.S. are not among the global leaders. International measures of science and math achievement in U.S. schools continue to show that our high school graduates are not among the global leaders in these subjects. Furthermore, the percentage of U.S. high school graduates who are both interested in and

[1] Thomas Friedman, The World is Flat: A Brief History of the Twenty-first Century, Farrar, Straus, and Giroux 2005.

prepared for the study of engineering is only about 5%[2]. This is considerably lower than it was several decades ago. Data from other nations reveals a general pattern that, with few exceptions, as each nation's wealth increases, interest among its youth in careers in engineering simultaneously decreases. Since the U.S. remains wealthy by international standards, it is not surprising that we also struggle with attracting bright young people into the study of engineering. Reports indicate that students feel that careers in medicine, law, and business offer more prestige and higher compensation than careers in engineering.

Studies also show that the U.S. public does not have a good understanding of what engineers do, and what they do understand they are not particularly impressed with. In general, engineers are perceived as socially inept people who are often obsessed with things rather than people, and frequently absorbed in esoteric, theoretical explanations. Public respect for the profession is not high. In a recent survey by Harris[3], the profession of Engineer ranks 10th out of 22 professions, just below Farmer and just above Member of Congress. In contrast, Medical Doctor ranks 2nd, Scientist ranks 4th, and Teacher ranks 5th. In addition, the public has a much more positive impression of scientists than engineers. For example, in a recent Harris survey commissioned by the American Association of Engineering Societies[4], the results revealed that about 70% of the population feels that scientists improve the quality of life, compared to only about 20% who believe that engineers do. Furthermore, about 80% of the population believe that scientists protect the environment compared to about 15% for engineers; about 80% believe that scientists save lives, compared to 15% for engineers; however, about 70% believe that engineers create economic growth, compared to 20% for scientists. Too often engineering is associated in the press with man-made failures and disasters.

Media representations of engineering and science are often problematic. As reported in a recent article in Nature[5], "*In film and television, scientists are often quirky, nerdy, obsessed, reclusive, self-important, and not infrequently, mad. These are not character traits that appeal to kids*." A recent study sponsored by the National Science Foundation investigating the impact of media on children's attitudes[6] revealed that many children who encounter real scientists and engineers in the classroom believe they aren't real. They might say the person was too "normal" or too "good looking" to be a scientist. "*The most heart-breaking thing is when they say 'I didn't think he was real because he seemed to care about us*.' "[6] Young people are often more altruistic than adults, and the perception of motivations is particularly important in gaining their interest. As a result, recruiting children to consider a career in engineering is made much more difficult by negative public perceptions presented and reinforced in the media.

Who Are "the Right People"? The National Academy of Engineering recently published a report[7] in which they outlined the changes needed in engineering education to prepare the engineering workforce for the foreseeable challenges that lie ahead. Among the observations and recommendations they put forward are several specific competencies that they believe will be of increasing importance. These include[8] "*team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies*" and also "*creativity, ingenuity, professionalism, and leadership*." These new competencies are not meant to replace the current high standard of technical competence, but rather to supplement it.

The new competencies are meant to strengthen the leadership of the U.S. in technological innovation. They are aimed at producing graduates with more than the basic engineering and

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[2] Richard Noeth, et al., Maintaining a Strong Engineering Workforce, ACT Office of Policy Studies, 2003
[3] Harris, Most Prestigious Occupations, 2006
[4] AAES/Harris, Surveys on the Public Understanding of Engineering, 1998 and 2003
[5] Jonathon Knight, Hollywood or Bust, Nature, Vol 430, 12 August 2004.
[6] Ibid
[7] Educating the Engineer of 2020: Adapting Engineering Education to the New Century, National Academy Press, 2005.
[8] Ibid, pp. 51-52.

science competencies. Specifically, they aim to produce innovators who are capable of creative insight and invention across disciplines. Also, they aim to enhance the entrepreneurial competencies of engineers so they are better able to recognize opportunities and eager to take initiative to make an impact. As a result, the engineering workforce they envision clearly has strong vision, a vibrant imagination, and a passion to make a positive difference in the world.

Of course, the engineering workforce must continue to demonstrate technical competence in the basic sciences, mathematics, and engineering design. But since the rate of invention of new technologies and ideas continues to accelerate, many of the most important technologies that will dominate the careers of today's engineers haven't yet been invented. So, the engineering workforce must also be prepared to learn independently and throughout their lifetime. They must not be intimidated by challenges for which they do not have accepted "prerequisites," and instead they must be fearless and persistent in their pursuit of new knowledge. They must know how to learn and to use the talents of team mates to develop practical solutions.

A particularly useful framework for organizing these many competencies is provided by Howard Gardner's theory of multiple intelligences.[9] Gardner proposes that all people have a complementary set of largely independent abilities or "intelligences" that work together in practice to allow them to solve problems and fashion products of value within their culture. According to Gardner these intelligences include (1) linguistic, (2) logical-mathematical, (3) spatial, (4) bodily-kinesthetic, (5) musical, (6) interpersonal, and (7) intrapersonal intelligence. According to Gardner, each of these intelligences is present in all humans, and localized to specific areas within the brain in varying degrees, as demonstrated in studies of individuals with brain damage, educational development in individuals with unusual abilities and inabilities, historical investigations of human evolutionary biology, etc. Gardner points out that in the 20th century, American higher education focused on the first two intelligences as fundamental to intellectual achievement. The next three are often regarded as the basis for artistic achievement, and the last two for success in social settings, including marketing, management, and influence. He reports that such quantitative indicators of overall intelligence as the IQ test and the SAT test are largely correlated with the first two forms of intelligence.

Interpreting the engineering competencies recommended by the National Academy of Engineering within the Gardner framework of multiple intelligences, it is clear that the NAE is calling for an engineering workforce with better developed intelligences in both the creative and social dimensions. Since Gardner's intelligences are largely independent, the creative intelligences are not well correlated with the analytical intelligences of linguistic and logical-mathematical reasoning (which currently form the basis for admission decisions to many universities). Similarly, the social intelligences (interpersonal and intrapersonal) are not well correlated with the analytical intelligences. Hence, the NAE is calling for a broadening of the competencies and the abilities of the engineering workforce to include these non-analytical dimensions.

If the engineer of 2020 is better able to work creatively and to innovate, s/he is expected to have better developed intelligence in the areas of spatial, kinesthetic/bodily, and musical reasoning. In addition, if the engineer of 2020 is better able to communicate, work in teams, lead, and form entrepreneurial enterprise, s/he is expected to have better developed intelligence in the areas of interpersonal and intrapersonal reasoning.

It seems logical to conclude that if we aim to produce graduate engineers that are more broadly competent, then we should expect to be more successful in achieving this goal if we seek to admit incoming students with broad ability in these non-analytical areas, and if we then structure our educational program to cultivate and enhance these abilities. That is a deliberate strategy at Olin College.

[9] Howard Gardner, Frames of Mind: Theory of Multiple Intelligences, New York: Basic, 1983

How Do Most Admission Programs in Engineering Work? There are about 300 undergraduate engineering programs in the U.S. The large majority of U.S. engineering students are enrolled in programs that reside in large universities in which engineering is one of many options that students may choose upon matriculation. Most of the large research universities are publicly supported. The remaining small percentage of U.S. engineering students are enrolled in programs at small undergraduate colleges, including some liberal arts colleges and a handful of undergraduate colleges with a science and engineering focus, like Olin College.

Admission programs vary from institution to institution, but nearly all engineering schools require applicants to submit application materials that include transcripts of high school courses completed, including grades and also standardized test scores[10]. These test scores are usually either the SAT or ACT exams, which are nationally normed. Particular attention is usually directed at evidence of high achievement and ability in natural science and mathematics. Since many thousands of applications are involved at large universities, most engineering programs base their admission decisions on an analysis of only these written materials.

Some selective engineering schools also require an essay. Very few go beyond this to require a personal interview. The numbers of applicants involved are so large at the undergraduate level that it is very rare to require a personal interview for an admission decision for every first-year student in the program.

A significant number of schools require an interview for a select small number of scholarship recipients (presidential scholars, etc.), but not all incoming students. However, when interviews are required, they are often individual interviews that are not aimed at observing teamwork ability. Furthermore, these individual interviews rarely involve providing a group design challenge in which the creativity, resourcefulness, and teaming ability of candidates can be observed first hand.

As a result, the admission process in most engineering programs is based largely on written measures of analytical ability of applicants with much less emphasis on creative or social abilities[11]. That is, most engineering schools do not attempt to identify and recruit students with the broad abilities called for in the NAE report.

In addition, many engineering students in the U.S. report that they chose engineering as a major because their high school math or physics teacher recognized their talent in those subjects and suggested to them that they might be well suited for a career in engineering. It is very uncommon for a high school student who is recognized for creativity or entrepreneurial thinking to be directed toward engineering. Students with high ability in math and science but also broader creative and social abilities and interests are often directed to other fields—like medicine or law—by parents, counselors, and teachers.

Candidates' Weekend and the Olin College Admission Program. Olin College has established a distinctive admission program intended to address many of the concerns identified above. The program is intended to recruit students with the abilities and motivations needed to become the engineer of 2020 as described by the National Academy of Engineering. This includes strong ability and achievement in math and science, but also strong evidence of creativity and .curiosity, as well as strong evidence of teamwork and interpersonal intelligence.

The Olin admission program begins by identifying thousands of high school students who demonstrate strong analytical ability and an interest in engineering through the Educational

[10] Recently a few schools (such a Worcester Polytechnic Institute) have begun to experiment with admission criteria in which standardized test scores are optional. But very few schools are involved at this point.
[11] An interesting experiment recently began at Tufts University where applicants are required to write several essays as part of the admission process. The purpose of the supplemental essays is to provide a measure of the creative and practical intelligence of all applicants based only on written materials.

Testing Service and other means. Olin's printed view books sent to these prospective students send the message that Olin College is more about people than technology. The books also intend to send the message that engineering is a dynamic field that addresses important human concerns. In addition, the books communicate that the Olin program is student centered, that learning is fun, design is at the heart of our curriculum, and that entrepreneurial thinking and risk taking are valued and prominent in our culture. They also communicate that our community is nearly gender balanced and diverse, and that our primary goal is to prepare graduates for life, not just a career.

All applications to Olin College must be submitted electronically. Our web site plays a very important role in establishing an identity and a dialog with prospective students.

Last year about 1,000 applications were received for the Class of 2011. Each of these applications was read by several members of an inclusive admission committee on campus that consists of faculty, staff, and alumni. However, the faculty members on the committee have the greatest influence on admission decisions, reflecting the very close relationship between faculty and students that pervades all aspects of the learning experience at Olin.

After screening the written applications to identify those that appear to have ample analytical ability to succeed in the most demanding science and math courses at Olin, the pool of applicants is reduced to about 180 who are invited for mandatory interviews on campus. In particular, the admission committee selects the candidate pool so that the average GPA is nearly perfect, the SAT scores (or equivalent) rank in the top 1% nationally, and the rigor of the academic program taken in high school is as high as possible. In addition, to the extent possible within the pool, the committee also attempts to obtain gender balance; wide geographic, cultural, socio-economic, and ethnic diversity[12]; appreciation for philanthropy and entrepreneurship; broad talents and interests beyond math and science; high spirits and willingness to take appropriate risks in life; and also in possession of a good understanding of the unique learning objectives and philosophies of Olin, so that matriculation at Olin would be a good fit from the perspective of the student as well as the College. At this point in the process, all candidates are considered of equal status, and all written application material is set aside.

The approximately 180 "candidates" for admission are then required to attend one of two "Candidates' Weekends" (CW) in late February/early March. To help insure that all candidates attend the CW event, Olin College provides a partial subsidy of the travel expenses for all students, with a sliding scale where those who travel long distances receive greater subsidy. More than 95% of the applicants invited to attend a CW event typically accept our invitation and attend.

The CW events are designed to allow Olin College to assess the creativity, interpersonal intelligence, and motivations of each candidate in order to make sound decisions on which students are a good fit for our program. Equally important, the CW events are designed to allow each candidate to learn about Olin College in depth and decide whether its philosophy and approach are a good fit for her/him. The events are distributed over two days, and parents are invited to attend a special program as part of the weekend activities.

The CW events include a non-evaluated team design exercise in which randomly selected groups of five candidates are asked to work together for several hours to build a device for competition with other candidate teams. This serves to "break the ice" in an otherwise very intense weekend, and sends the strong message that Olin values team work and design in light-hearted competition.

[12] Currently the College limits the percentage on non-U.S. citizens among the first-year students to approximately 5%.

Other events during the weekend include small group exercises and also individual interviews that are evaluated by small evaluation teams assigned to each group. These evaluations assess the communication skills, creativity, maturity, breadth of interests, and interpersonal skills of candidates.

After both weekends are over the admission committee reconvenes to assemble the evaluations and make final decisions on admission. The decisions take into account all the evaluations from multiple evaluation teams, and the class is selected to maximize the fit with Olin's mission and philosophy, and also to maximize the likelihood of academic success of each admitted student. In order to obtain an incoming class of about 85 students, a total of about 100-120 students are offered admission. In addition, a few students are offered a position on the "wait list" for admission. All admitted and some wait-listed students are offered the opportunity to defer admission for up to two years with full scholarship, provided they have a reasonable plan for the use of the deferred period.

The Olin College admission program may be unique in higher education for its thoroughness and intensity. It provides greater opportunity to assess the non-analytical intelligences that Gardner has identified, and it also provides extraordinary opportunity for candidates to assess their personal "fit" with the Olin College community. Ideally, each student who selects Olin College will feel that it is his/her first choice among all options for an undergraduate engineering education.

Summary. The admission program at Olin College is intended to attract "the right people" into engineering, to produce the engineer of 2020. It is also intended to maximize the academic and personal success of each admitted student. The program takes into account both analytical ability through standard written applications, and also creative and interpersonal ability through on-campus group and individual interviews. Both faculty internal to Olin College and employers external to the College are pleased with the quality and broad interests and abilities of the students produced by this process. The first two classes established a combined 4-year graduation rate of more than 90%.

It is difficult to adequately describe the quantum change in character of the admission process that is enabled by Candidates' Weekend program. For this reason most members of the Olin community agree that personal observation of the event is necessary to fully appreciate the significance of the opportunity it provides for enhanced admission decisions. From both the perspective of the College and the prospective student, the activities provided during these weekends allow much more information and authentic assessment of the potential match in expectations and opportunities.

To help focus the discussions after observing the CW events, the following questions are provided for members of the Olin community and our guests:

1. What do you feel are the most important processes at work during the weekend, from the perspective of the prospective students and their families, and from the perspective o the College?

2. Did anything you observed during the weekend surprise you? If so, what?

3. Do you have any suggestions for improving the CW program?