Demystifying the ‘E’ in STEM

While my generation had “Q” as the engineer from the James Bond thrillers, our students might associate with Tony Stark, creator of the Iron Man superhero. Analyzing Stark, an ingenious multi-tasking engineer, can be a good way to relate choice of major to a prospective engineering student. Each element of the Iron Man suit falls into the domain of a specific type of engineering: strength and durability – mechanical; supersonic flight – obviously aeronautical; solar powered life support – electrical and biomedical.

Students and counselors are often intimidated when it comes to understanding STEM majors, especially navigating the highly specialized, segmented divisions of engineering majors. There are many engineering degree programs and each has an array of sub-specialties. The table below gives an overview of some mainstream engineering degrees:

Degree	What They Design and Build
Mechanical	static items (buildings, bridges), moving systems (cranes, ski lifts, automobile suspensions, disk drives, ball bearings), energy conversion and fluid systems (engines, boilers, pumps, tanks)
Civil	earth-moving construction (foundations, dams, canals, flood control), roads, earthquake resilience
Chemical	large-scale manufacturing of chemicals (plastics, pharmaceuticals, food, paint, fertilizer)
Aeronautical	fixed wing and rotary wing manned and unmanned aircraft, rockets, spacecraft
Biomedical	systems to measure physical parameters (CAT-scans, blood-oxygen monitors) or perform medical procedures (dialysis machine, laser scalpel) or supplemental body parts (stents, heart valves, ligaments)

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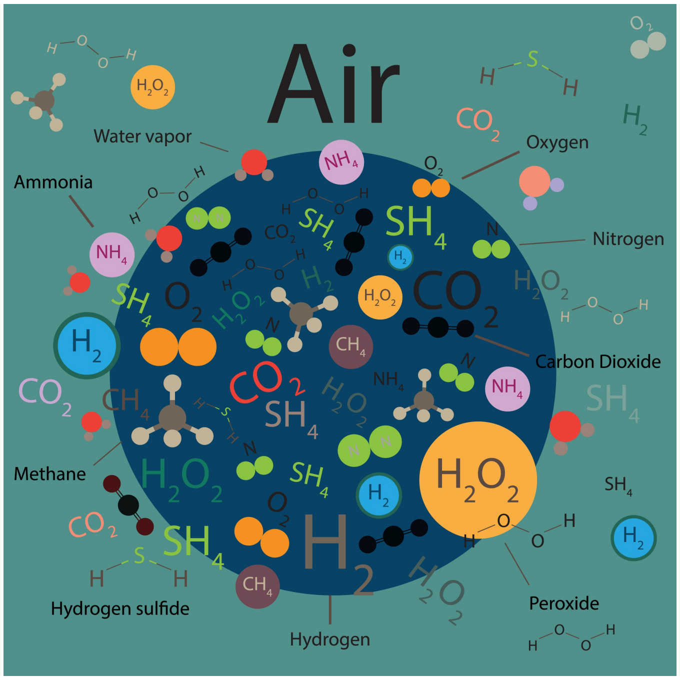
Industrial	assembly line processes (bottling plants, manufactured goods), and worker-machine interface (time-motion systems)
Electrical	power systems (generators, motors, power lines, transformers, solar cells, batteries), electronic equipment (computer chips, motion sensors, DVD players)
Nuclear	power plants (nuclear reactors), medical devices, and industrial instruments (radiation sources and measurements)
Computer	integration of electronic calculating and memory components, software, and input-output components into a working system
Naval Architecture	ship strength and power; steel, aluminum, fiberglass, wood manufacturing; ship systems (propulsion, propellers, and payload), and submarines

Mechanical and civil engineering vary primarily on scale. The civil engineers deal with huge developments like dams: moving thousands of cubic yards of earth, pouring dozens of truckloads of cement, and making sure it all holds together during freezing weather or earthquakes. When you see a huge public works project like a new interstate highway or the foundation for a sports stadium, you know a civil engineer was involved. Mechanical engineers often work on much smaller items, down to the buttons on your cell phone. Mechanical engineers work to balance all the forces moving the world and hold them still: gravity, acceleration, momentum, and friction. When they do, the results can be magical: a roller coaster or a NASCAR racer, a Mars rover or an artificial limb. You can spot a future mech/civil engineer working on her bike or motorcycle, taking wood and metal shop classes, or building Lego models.



Chem E students are concerned with one major transition from high school: how to take what they did in their chemistry lab and supersize it! Instead of beakers and test tubes, they get to play with giant vats of chemicals. Chemical engineering students learn to juggle a number of variables and have to be comfortable with uncertain outcomes; even though 2+2=4, H_2 and O_2 can yield H_2O or H_2O_2. Being successful in the major requires significant leaps of imagination. Just as nothing in a caterpillar tells you it is going to become a butterfly[1], nothing in a bottle of propane tells you it is going to become Tupperware. Although the basic skills of high school chemistry (accurate lab work, an understanding of chemical reactions and properties) are indicative of success as a chemical engineer, an unconventional success factor is an interest in cooking, especially baking, which is the closest most high school students get to a home chemistry lab. In

Sous Vide

fact, Microsoft’s former chief technology officer, Nathan Myhrvold, runs a modernist test kitchen called The Cooking Lab.

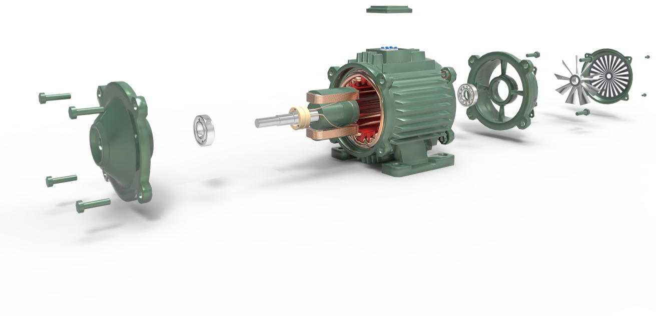
Aeronautical engineering students can draw inspiration from the countless movies about air and space. *Top Gun, Apollo 13*, and *Interstellar* all give high school students a feel for the romance of being in aviation and space, but it’s not all “yippie-ki-yay” and “failure is not an option”. Being an aeronautical engineer means performing analysis of three-dimensional airflow in the lab while running numerical simulations on the computer. Aeronauticals work on making things simultaneously light and strong; to bring these contradictory properties together, they use exotic materials like titanium and carbon fiber. In addition to space, the aeronautical engineering major can find a career working where the winds blow: wind power turbines, skyscraper design, and automotive. Model rockets, model planes, paper airplanes, and quadcopter drones are all favorite toys of a future aeronautical engineer.

NASA Flight Director

Gene Kranz

Biomedical is a marriage of several engineering disciplines (chemical, mechanical, electrical) with a consistent focus on medical devices, systems, and measurements. Because the systems work in conjunction with the human body, the study of biomedical engineering covers biology and interfaces between the body and the system. If a student is passionate about science fiction, and has read Neuromancer by William Gibson, they have been given a vision into the future of biomedical engineering. Other fun examples are *Robocop* and *Terminator*, and for those of us of a certain age, *The Six Million Dollar Man.*_

Industrial engineers put it all together – or so says the t-shirt. If you hear the term ‘assembly line’ or watch equipment being erected by people and robots working together, you can bet an industrial engineer was involved. Picking, placing, connecting, welding, inserting tab A into slot B, designing an IKEA bookshelf – all of these are examples of what industrial engineers work on. They also study the person-machine interface – the way a tool can be controlled and provide feedback to the user. While this may sound low-tech, just ask any student who’s used a Kinect to control an Xbox or felt the tactile feedback of a haptic interface – industrial engineering is full of technology.



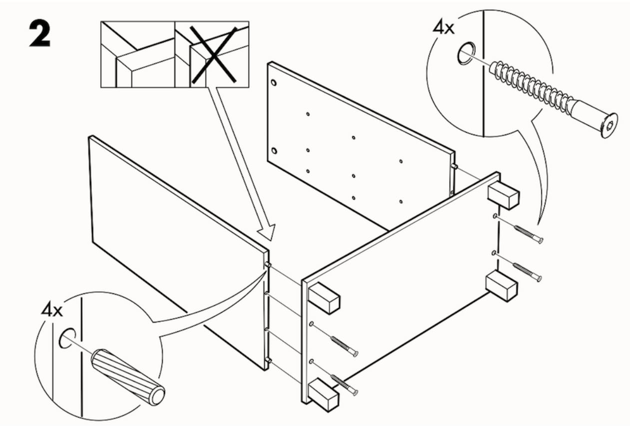
Electrical engineers work on really big stuff like generating plants, electric motors, high-voltage power lines, and minivan-sized transformers. Or they work on really little stuff with prefixes like nano and pico. Double E’s speak the language of megawatts, kilovolts, diodes and transistors. They employ the underlying mathematical equation that defines it all: Maxwell’s equation of electromagnetic fields. Have you ever seen a youngster walk around the house with a magnet, trying to see what it sticks to? That is the future double-E major, who will someday be able to explain to you why it sticks, and calculate how much force that magnet creates on different materials. Amazing, you say? Nope, just another partial differential equation in the day of an electrical engineer.

For a quick overview of the many disciplines of engineering, along with a few others, take a look at the US Department of Labor website. Professional associations are also an excellent source of information. All the major types of engineering professions have an association, and part of the responsibility of each is outreach and education to the future generation of engineers. Let’s take as an example the American Society of Mechanical Engineers. Checking out the ASME[2] page on Career & Education, a student can see that mechanical engineers work on problems like sport wheelchairs, earthquake-proof homes, and 3-D printers. The student can also find information on internships, like at NASA, and high-school level activities that can give them a taste of what engineering is about, like the Gravity Racing Challenge. All the major institutes and societies – IEEE, AIChE, SNAME, SPE, SAE, ASCE, ACM, AIAA, and BMES – have information to help you and your students understand their professions.

If a student wants to be an engineer, she needs to study engineering. There are a few paths to the end result, but each passes through an ABET-accredited engineering college. While it is common to see engineers transition to other industries, moving the other way into engineering is unlikely. Sometimes we see successful transitions from other STEM undergraduate programs like Physics or Math into engineering professions, but the more theoretical the education, the harder the transition. This is because engineering education focuses on discovering solutions to real-world problems with achievable and commercialized technology, whereas the more purist physics and math undergraduate educations do not focus primarily on practical applications. Why try to push a rope uphill (to use a frequently-stated engineering analogy)?

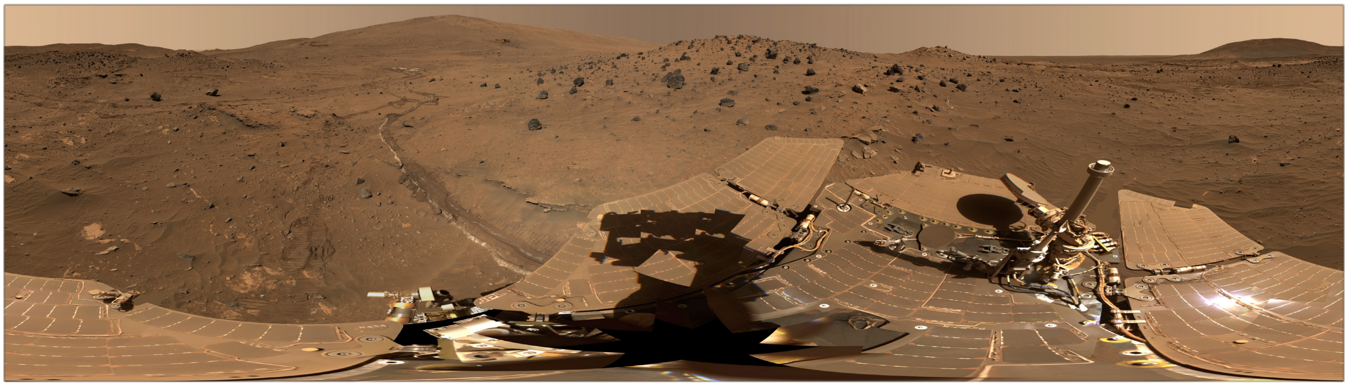
We know from working with students that their post-college career is really abstract in their minds; even after using the available tools to research different types of engineering, determining one major may not be clear or easy. Fortunately, many engineering undergraduate programs understand this need for personal growth and have structured their first years as exploratory processes in which students get the basic tools applicable to all engineering, gaining an immersive awareness of multiple engineering disciplines. As such, the student does not have to commit to a major up front, but rather commits to engineering. Purdue, for instance, has a first-year common program in math, physics, chemistry, and engineering concepts for all engineering students, and only in their second year does a student get admitted to one of the professional schools of engineering. On the other hand, The University of Texas at Austin allows the applicant a first and second choice engineering major from their array of nine engineering programs, requiring the prospective student to choose before entering college.

Another major question is the type of engineering education best suited to your student: a ‘techie’ education where the non-engineering classes are limited to the minimum needed for a degree, or a liberal arts education where engineering is taught alongside critical thinking skills and humanities. An



example of the latter exists at Columbia University, which since 1959 has made its core courses mandatory for engineering students: “In order to find solutions to the world’s most pressing problems, you have to fully understand the world around you”. For students who are a better fit for a primarily technical education, an example exists at the California Institute of Technology. At Caltech, an undergraduate typically takes 20% of their credits in the humanities and social sciences. Of course, you will have to trade off the fit criteria for an individual student: is her reduced interest in humanities something that would benefit from a liberal arts engineering education, or would it force her to struggle as a square technical peg in a round liberal arts hole? Famously, Bill Gates and Steve Jobs had opposite views about the need for STEM with or without liberal arts, and there is room for both of these visionaries and their legacies.

Engineering isn’t a passing fad but rather a vital part of our 21st century economy. There is a difference between the historical tinkering inventor and the engineer of today. Both have in common George Bernard Shaw’s idea that “I dream things that never were; and I say, 'Why not?'” What has changed is the amount of collaboration needed to create successful and usable products. While Stark can do all types of engineering himself, in the real world, an engineer is a member of a team, bringing one of many diverse skills to attack a problem. When NASA put together the Mars Lander team, they included the following engineers: mechanical, power, thermal, controls, avionics, electrical, robotic, software, and systems.



This emphasis on collaboration is one of the major differences between the high school and undergraduate experience. The high schooler is measured mostly on her own merit, and ‘collaborating’ is sometimes punished as an ethics violation. As a college undergraduate, there is a strong emphasis on team effort: term projects, lab analysis, and shared team grades are vital aspects of the engineering education, particularly for juniors and seniors. Developing collaboration skills is a significant personal growth objective for budding engineers, as it is an important part of the working professional’s ability to deliver results. I’ve heard it said that we spend K-12 teaching children about individual responsibility and personal achievement, send them to college and grade them on a curve, and then employers have to devise all sorts of team-building exercises to get these new hires to work together. Look at a college’s overall offering of required and elective courses and extracurricular enrichment opportunities to see how well their engineering majors gain experience in collaborative teamwork.

Perhaps there are two reasons for the current burst of interest in engineering: demand and awareness. The range of professions requiring an engineering degree has grown enormously in the past 30 years, and engineering touches our lives on a daily basis more so than in the past. Engineering is, surprisingly, many seemingly unrelated disciplines. While one engineer may be creating bacteria fermenting systems to produce vitamin C, another engineer is calculating the strength of curved beams in a new bridge. Even within the field of electrical engineering, a young graduate could choose to work on high-efficiency wind turbine generators or a super-microprocessor for robotic vision. Awareness is the other factor for increased interest. As technology has crept into our daily lives, we more closely recognize the engineer’s value. When engineers from long ago were locked up in top-secret Cold-War facilities, like Lockheed’s Skunk Works, we saw neither the process nor the end result of their work. The closest we got to daily application was watching and using our microwave ovens. Today, our lifestyle is built on products and services that are dependent on engineers to create, construct, and continuously improve.


Hoover Dam and Memorial Bridge

Furthermore, learn a little about each of the engineering disciplines on professional societies’ websites. Above all, understand that engineering is not a single educational subject, but rather one which appeals in many different ways to students who all share an interest in asking: “Why not?”

[1] R. Buckminster Fuller

[2] www.asme.org/career-education