# The Three Faces of Engineering

**Mohamed Gad-el-Hak**

*In honor of National Engineers Week (16–22 February 2014)*, *I share some thoughts on the Three Faces of Engineering—creativity, art, and science—and what we can do to strengthen our teaching of engineering to students of all levels.*

Engineering is a human endeavor whose primary goal is to improve the quality of life. Engineers strive for healthier, happier, and more prosperous societies. Modern engineering encompasses three equally important facets: creativity, art, and science. In 1947, the American Engineers' Council for Professional Development, predecessor of ABET, the professional organization that accredits engineering and engineering technology colleges, defined engineering as:

> "The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation or safety to life and property."

Never mind the unrefined English (engineers can't write, or so an adage muses), there are three faces of modern engineering, science being one of the aforementioned triad. But this was not always the case. Millennia ago, the ancient Egyptians built the pyramids and the Romans constructed a system of aqueducts, long before modern science even existed. Eons before civilization, the purely trial-and-error approach archaic Homo sapiens practiced when making spears, arrows, and other hunting tools is a manifestation of the engineering art.

Ancient technology had only tenuous links to the science of its times, which was heavily slanted towards geometry and astronomical observations. Modern engineering, on the other hand, deals with much more sophisticated systems and strives to manufacture affordable, competitive, optimized products. Scientific principles play a dominant role to design and produce such systems/products. In 1781, James Watt invented a version of the steam engine, and his artifact was a main driver of the concept of mass production and the industrial revolution to follow. Thermodynamics, a branch of the natural sciences, was developed out of a desire to increase the efficiency of early steam engines.

Modern science emphasizes the importance of experiment over contemplation. This non-Aristotelian science is inscribed in the work of Nicolaus Copernicus (1473–1543), Galileo Galilei (1564–1642), Isaac Newton (1642–1727), Gottfried Wilhelm Leibniz (1646–1716), and James Clerk Maxwell (1831–1879), among others. The space shuttle, considered the most complex machine ever built, would not have been possible without the powerful predictive tools those modern scientists have gifted to humanity.

Ideally, engineering students have to be grounded solidly in mathematics, physics, chemistry, biology, and similar sciences before learning the art of engineering. In France, for example, engineering college students do not enroll in any engineering classes until the fourth year of a five-year program; the first three years being devoted to the humanities, mathematics, and sciences. Students in the United States start their engineering courses a bit early simply because undergraduate engineering degrees are typically completed in four years.

But starting about two decades ago, the art of engineering was taught at the freshman level. This was done to attract, engage, and retain future engineering students who eagerly called for an early hand-on experience. Pressures to recruit future students mounted, and this necessitated the teaching of 'engineering' classes at the high- and middle-school levels. But in all these cases, the students were not quite ready yet to learn science-based engineering. Calculus and calculus-based science come later.

This is all good if it means successful recruiting to the ever-expanding engineering colleges. The country needs more engineers, and this is what it takes to convince young minds to enroll in what is perceived as a difficult major.

But all good things have a down side. In this case, it leaves the student with the erroneous impression that modern engineering can be learned and practiced without a strong foundation in mathematics and physics. The delayed shock reaction comes later at a price. When the students are faced with engineering science classes, which are heavily dependent on the calculus-based laws of nature, they howl, "This is not what we signed for". The students wish to continue what they have started, which are to make paper airplanes and engage in egg-dropping and object-catapulting contests. The undergraduates begrudge classes that require them to model, compute, predict, and analyze. The problem-solving and critical-thinking skills acquired in engineering science classes are needed to tackle global warming, to provide sustainable energy and fresh water, to erect optimal living spaces, and to create competitive new and improved products from the needle to the airplane.

What to do? I believe early teaching of engineering is necessary. Even making engineering-related toys is not a bad idea, as those may fire the imagination of even pre-school children. But the students should be imprinted with the fact that creativity and art are only two faces of engineering. The third face, science, will be taught in due time.

This can be explained even to a five-year old, but the tutor has, first, to have the incentive to do so and not to kick the can down the road. And, second, has the comprehension and experience to know the difference between the trial-and-error art of engineering and the science of engineering. The former is what ants practiced for eons. The latter is what humans practice in the twenty-first century. The *Formicidae*'s quality of life is the same as it was when they built their first anthill. That of humans has been improving steadily. *Scire quod sciendum.*

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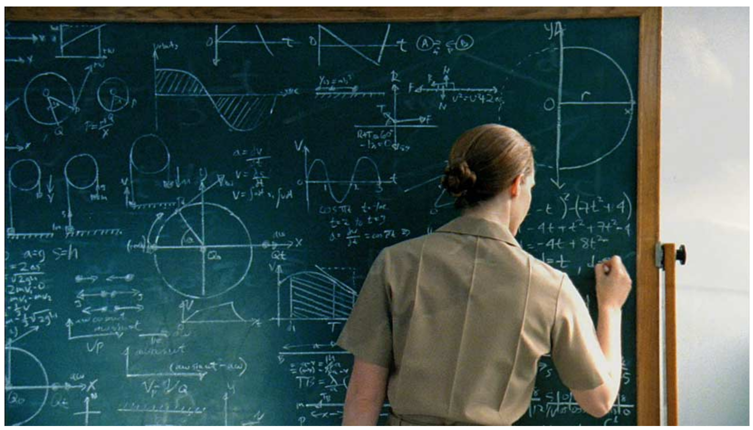
Appeared in PBS's *Science Matters*, (20 February 2014; http://ideastations.org/science-matters/special-report/three-faces-engineering), VCU's *Across the Spectrum* (21 February 2014; http://www.spectrum.vcu.edu/insight/the-three-faces-of-engineering/#.UwjAgF6pqLA), and *Mechanical Engineering* magazine (May 2014; http://www.memagazinedigital.org/memagazine/may_2014#pg18).

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