REHUMANIZING ENGINEERING

by

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To talk of formal engineering education in a country where it started is a folly. To talk about the future is another folly. Almost everyone who has spoken of the future of engineering has been wrong. Fools rush where angels fear to tread. This double-folly tract must continue with the courage that comes from innocence.

Engineering will change in the future. That is a prediction with a reasonably high level of confidence. To predict how it will change is another matter. It is not frivolous to look back before speculating about the future changes with the understanding that no looking back is without bias.

Whether one goes by Tredgold's optimism," directing the natural sources of power for the use and convenience of man," or by Veblen's cynicism, "a profession of sheep educated at great public expense to do the bidding of corporations," engineering is a human enterprise. Human history does not repeat itself. The mistakes are repeated. Judging the future of a human enterprise by its past is likely to be a mistake almost as often made as judging past events by the criteria of the present. But it is less of a folly than ignoring the past and starting from first principles to derive the future shape of things.

The saga of engineering cannot be cleanly separated from that of other societal enterprises until the time engineering education was formalized (Schemnitz Mining Academy, 1733) and civil engineering defined as an academic discipline (Ecole des Ponts et Chausees, 1747). Agamemnon's "fast ships" required engineering as did the accoutrements of the war-horse. Engineering stood close to war for much of human history. The qualifier "civil" is a strong reminder of that era even though it was used initially to identify those engineers who were not in government service. (Considering that the main function of government has been defense, a euphemism for the capability to make war, the differentiation appears consistent.) Indeed, engineering might not have survived the dark of ages of western society when there was hardly any commerce, had it not found its sustenance in war and faith. The reappearance of stone bridges in Europe coincides with the crusades.

Starting in 19^{th} century, when the causes of major conflict shifted from royal whim to economic need, engineering moved in with commerce, but it was still married to strife. The pseudotechnical justifications for different railroad track widths had their roots in the warlike competition for sales. Near the end of the second millenium, engineering is still close to commerce. There have been no changes in that alliance. But the external factors have changed. The time may have come to move in with what always received lip but not dedicated service from engineering: preservation of resources.

There are also changes in the internal factors exemplified by the strong shift in the role of analysis. To cite an example, the theory of elasticity to many branches of engineering was as monotheistic religion was to society. By explaining from a small set of axioms a wide range of observations and by providing the rationales for successful design prescriptions, the theory of elasticity was of great service and disservice to engineering for the same reason. By eliminating much of the mystery of material response in a certain range of loading, it liberated every trained engineer to make decisions from first principles that could travel from material to material and entity to entity in beguilingly intact form, at least on the surface. At the same time, it enslaved engineers to accountancy. Suddenly, the practice of engineering became comparable to operating a sewing machine in a sweat-shop. It also closed engineer's minds. Generations of engineers were trained with a blind eye to the abstractions presented by the definitions of unit strain and unit stress and the unforgiving relation between them.

At mid-century, the practice of engineering was characterized by repetitive calculations carried out by roomfuls of drones. The educational system supplied the drones under the banner of education in scientific analysis. Sometimes it was called "advanced" analysis and sometimes "refined" analysis in the interest of putting one school ahead of another, but it was drone work except for the few who led the pack.

In mid-20^{th} century, the descendants of those who objected to the invention of writing in Egypt (because writing would make a person's ability to remember atrophy) and abhorred the introduction of the slide rule (because it would make engineers forget how to multiply and divide), reviled the coming of the digital computer for similar reasons while misinterpreting its function to be simply that of a substitute for the slide rule. The one statement that captures the role of the computer in engineering is, "computers make bad engineering worse." Computers have liberated the good engineers from doing the work of drones. The professional engineer of the future will spend more time in decisions of judgment and less on repetitive calculations. The digital devices, created by engineers, will change the nature of engineering activities.

The age of reason led to the 20th century optimism that many of our social problems might be solved through wealth produced by modern technology. It was argued that social problems were intractable but if one transposed the societal hurts to their equivalent in material needs, purely technological solutions could be found to the human condition. It is not too early to call that approach a failed hope. This does not mean we need to throw out technology as a tool for helping solve social problems. New strategies that combine technological and nontechnological remedies need to be tried. The people who will captain this enterprise will have to have innate knowledge of the technologies, of the sciences, and of the human condition.

At the end of the millenium, that is where we are. Engineering academies will have to agonize over the decision. Do we change our culture or do we ignore the opportunity? Can an engineer be so educated as to have a confident innate understanding of physics and still be sensitive to, say, Dostoevsky?

It is a valid concern to reason that mixing modes will reduce the quality of the technology. We do not want to make an inadequate planner out of a mind that will develop into a great stress analyst and only a stress analyst. That is not the choice. The embryo stress analyst will develop in that direction anyway unless he/she is driven away from engineering by poorly structured curricular demands. The choice is whether the academy can seek and foster talents who want to build or to manufacture but who also have an affinity for the humanities.

Engineering education is compelling. Pollsters have claimed that there is a strong difference between freshman and senior engineers. While freshmen are not that different on the whole in their perspectives and desires from those in other disciplines, seniors are said to be distinctly different. Some have even gone so as to suggest that the aim of engineering education is to make every student, after the first professional degree, sound like a doorbell from the same works. If we accept that engineering education is compelling and transforming, we may also accept that changes in the educational options may develop the professional with an ear for the needs of society without the necessity of his/her having to struggle with the educational system in order to develop such sensitivities.

If the humanist-engineer is a desired educational product, if he/she can be developed in school, and if that appears desirable, the question is how to accomplish that.

There are at least two basic sources of resistance: curricular and professorial cultures.

Let us consider the curriculum. Naturally, if new options are to be added, some of the existing requirements will have to become optional. The sciences are sacred. We are not going to tamper with the basic interlocking sciences (mechanics of solids, fluid mechanics, thermodynamics, transfer and rate mechanisms, electrical theory, and material science), but there is flexibility in the professional curriculum. Engineering teachers have known that they cannot teach everything about design but they can teach, if they care, the sensitivity to practice.

In all branches of engineering, there are two principles that are common and underarching: (1) difficult things must be made simple and (2) a good solution with today's science, tools, and materials is better than a perfect solution next year or even next week. I submit that these principles can only be taught by repeated examples, by showing how simple and satisfactory solutions have been obtained to complicated problems. Admittedly, success requires repetition and time, but it does not need to be repeated in every segment of a particular branch of engineering. The apt student can carry the paradigm forward. Room to accommodate the new challenge can be found in the professional curriculum.

Let us consider the professorial culture where, true to my senescence, I see ineffable trends. Let me limit myself to the business of structural engineering. In mid-century, the thinking in the field in the U.S.A. was dominated by the likes of Cross and Westergaard. Both eminent in mechanics but with a penetrating understanding of the practice of engineering in the interest of society, they did not only provide the examples of technical excellence but they and their equals chose the people who followed them on the basis of the promise of quality. Their success expanded the professional community. Soon it became necessary to standardize entry into and upward movement in the academic profession because of two primary reasons. One was the bane of empires. Decisions had to be made centrally because the center could not trust the "provinces." The other was even more tragic. The people who had to make the decisions did not have either the time or the interest to understand quality. It was much more efficient to make the decision on the basis of quantity. It is worthwhile to consider how this would work in, say, the arts. Painters would be judged on the basis of how many square metres of painted canvas they produce in a given year or a symphony orchestra would be judged on the basis of the decibels of sound intensity that the orchestra can produce. "Well," you will tell me, "that is art and our teaching is not." For those of you who would maintain that position, I have good news. We are there. The art is about ready to disappear.

I have been told that the many breeds of dogs we have today have all by one means or another descended from the jackal. Clearly, selective breeding can have a strong influence. Today we are breeding faculties on the basis of hard quantitative criteria. The faculties of the immediate future are likely to put their values in what they have learned by experience (except for a few who can overcome their conditioning). What fraction of this group will be willing to exchange the imperial bureaucracy with the small and the human?

I conclude not with a prediction but a prescription. To meet the challenge of the next millenium, we need to humanize engineering. To accomplish that, we need to provide opportunities and encouragement for engineering students to excel in branches of our cultural heritage such as history, classics, and literature, as well as in the engineering sciences. We also have to fight the so-far losing battle against the mandarin system of management from a distance. To begin with, we have to put our own house in order.