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TRENDS IN ENGINEERING EDUCATION[1]

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1. INTRODUCTION

ALAN SEEGER started his most famous poem with the lines:

> I have a rendezvous with death
> At some disputed barricade,
> When Spring comes back with rustling shade
> And apple blossoms fill the air;
> I have a rendezvous with death
> When Spring brings back blue days and fair.

We well may think of those words as we contemplate the state of engineering and its past and present relation to civilization. The rendezvous calling to us as engineers and teachers differs from Alan Seeger's. That was a rendezvous with death, but not with failure. In our calling of engineering education, we have a choice of a rendezvous with sterility and failure, or a rendezvous with progress and achievement which are helpful to society and associated with service to our groups of students. We who are in engineering education, and also all who are engineers, have been and are being sharply criticized for the outcomes of our labors; but it is to be remembered that much which is talked and written about education in its various levels and orders, including engineering education, and much which is talked and written about engineering technology is shimmering mirage instead of true substance. The fact is before us and is a background for what I have to say, but I can not elaborate upon this here.

[1] Address at annual dinner of the Middle Atlantic Section of the Society for the Promotion of Engineering Education, May 4, 1940.

Benjamin Franklin is credited with saying that prose writing should be smooth, clear and short.

The fact that constructive progress in engineering education is now stirring is demonstrated by such affairs as the admirable mutual relations arising from the activity of the Committee on Engineering Schools set up by the Engineers' Council for Professional Development, with which this society is so intimately associated; and also by such reports as that of our Committee on Instruction in English in the Engineering Colleges and of our Committee on Aims and Scope of Engineering Curricula, both of which reports were recently published. We may well wish that the latter committee had found it possible to take time to expound more fully the experience and evidence which established the underlying reasons for their beliefs and conclusions, for we know that the course of progress in erecting such a structure begins with examination of data or specimens and their statistical classification, as in the development of the various sciences. However, this report tells us that "engineering education rests on a foundation of science, of humanities, and of sound relationships rather than on the practical techniques of particular occupations or industries"; and it gives a summary of objectives which deserves to be read and pondered over.

I will here deal only with major influences. Details are treated in such Society for the Promotion of Engineering Education committee reports as have just been referred to, and in the special report prepared on behalf of the Committee on Engineering Schools of the Engineers' Council for Professional Development, entitled "Report on Status and Trends of Engineering Education in the United States." This report is long, but it is intended for personal study and annotation—for which reason it has no formal index. In what follows, I will try to be exact because philosophical discussion often takes the character of bartering misty thinking among the debaters.

As long ago as 1893, Professor R. H. Thurston said in a contribution to the *Proceedings* of this society; "Upon the thorough education of our engineers depends very largely the future progress of this nation." Quite recently, Dr. W. S. Learned, of the Carnegie Foundation, has expressed his opinion as follows: "I know of nothing more hopeful for society than to combine a good engineering education with a sound philosophy." Each of these pertinent sayings infers that we desire progress. But, what is "progress"? In reflecting over this some time ago, I formulated a definition—"Progress involves the development and satisfaction of wants which are of a higher order." That definition leaves us still drifting. What are "wants of a higher order"? Truly, we must look sharply to be sure that our rendezvous is with progress and achievement and not with sterility.

2. Relation of Engineering to Civilization

"To live, the early Egyptians had to tame the jungle, drain, ditch and irrigate their fields. This required not only technical advances, but a high degree of social discipline. But out of it came a pioneer civilization of the world." Thus speaks a recent analytical history of the world. The same statement of conditions may be made for the probably equally early settlements of the valleys of the Tigris and Euphrates and other favorable areas. Note that, to live, these primitive peoples near the dawn of written history had to "drain, ditch and irrigate." That is, it was on crude engineering that these primitive peoples relied, associated with a degree of "social discipline"; and on that combination was built their early civilization. Note, also, that the "social discipline" already was in the world among prehistoric people in Europe, who developed a crude engineering which enabled them to construct and live successfully in communities. The dwellers' relations in each community compelled the gradual formulation of codes of ethics and rules of morality. Professor George F. Moore, distinguished scholar and authority on the history of religion, has said: "Civilization develops only where considerable numbers of men work together for common ends. Such unity is brought about, not so much by community of bare ideas, as by community of the feelings by which ideas are emotionalized and become beliefs and motives." He farther points out that political, geographical and climatic, and economic features are not to be ignored because they may explain peculiarities of particular civilizations, or their rise or fall—but they "do not account for civilization itself."

Thus the seeds of civilization were sown, and engineering aided in that sowing. Engineering and civilization ever since have marched together—each encouraging and influencing the other. As the experience of man over the untold thousands of years enlarged his intelligence, he improved his engineering and his civilization profited by it. Communication became more readily accomplished between man and man, between community and community, and even between tribe and tribe; so that practices which added to safety, convenience and comfort among one group became known and used among other groups even in distant places.

Cupidity (greed) and the lure of barbarous excitements seem to have been among the first intrinsic human qualities, and they still are intrinsic. The two influences—(1) engineering with its possibilities for providing health, comfort, convenience and opportunities for happiness and (2) the innate cupidity coupled with love of barbarous excitement—are antagonistic and have been so as far back as records go. Murder, arson, cruelty, corruption, immorality, slavery and brutal wars are dominant features of the records of all parts of the world for which records remain. If there has been any change in the extent and repercussions of these horrid activities of man, I am willing to place my wager on their having become ameliorated (considering the world as a whole) century by century during the ages only a little.

Those who paint the bad state of present-day civilization compared with the periods long gone by are not scattering original thoughts. That same plaint has been heard for millennia of years; and if the retrogression has so continued through the years, our far ancestors must have been veritable angels—or else we now are in terrible case. I have discussed this at greater length in a small book entitled "Engineering's Part in the Development of Civilization," which is published by the American Society of Mechanical Engineers. This is a book intended to be read thoughtfully and reflected over for the purpose of getting a better understanding of where we stand as engineers, why we are here, and the what of future opportunities and responsibilities for engineering. However, not all the learned ancients were sure the world was retrograding—which also is true of some of our moderns.

I already have referred to the application of crude engineering in drainage and water distribution in the early settlements of the Valley of the Nile, the Valleys of the Tigris and Euphrates, and elsewhere, which enabled the several peoples to live under favorable conditions for their early times and to develop notable civilizations of their particular types. Most of those developments lost their status as a consequence of external and internal wars. The peoples possessing, for their times, highly developed arts and technology fell before cruder and more hardy hordes. Why this should be is not clear. Many questions stand unanswered. Did the more leisurely life of art, agriculture and technology cause in the civilized groups a touch of abstraction and indifference and a softness which made them incompetent for self-protection against the invasions of barbarians? Was the overthrow in all cases the result of war? If not, what were the causes underlying the downfall where barbarian war was not the cause?

Especially, was loss of engineering skills and techniques the primary cause of the downfall of Persian and Arabian civilizations; and of the Arabs in North Africa toward and after the middle of the Christian Era? What of the Mayans and certain of the ancient tribes of the South American Andes? Were their engineering skills (great as they were for their times) inadequate to enable them to cope with changing climates or other natural cataclysms, which left only the alternatives of adaptation or extinction? If we had the answer to all these and some like questions, then we might correctly appraise our present state.

It seems to be a determined historical fact that small parcels of land alone, farmed by individual families, can only support such families in relative poverty. In the same geographical locations, large land-owners can become individually wealthy through purely agricultural interests, but only by the utilization of human slavery or the exploitation of driven hired-workers. The introduction of local mechanical industries and general commerce changes all that. The cheapening of needed industrial products and the increasing local demand for foodstuffs and for raw materials for the industries make it possible for the small land-owners of intelligence to farm with moderate profit and improve their level of living, and also possible for the large land-owners to maintain moderate wealth while subscribing to reasonable conditions of work and pay for their workers.

Much of the apparent failure to learn by historical precedents is due to the fact that the world is new in its relation to the minds of each generation; and generations have an unconscious wish to find the way by original experience through the processes of trial and error. It is in the nature of immature men to be wishful thinkers. The same fault is strengthened by the practice of historians in former generations to extol the glories of dynasties and of military victories, and say little about the lives of the masses of people and the social, economic and technological conditions surrounding them. Historical treatises therefore have provided no sufficient touchstone with which to test the effects on the life of the masses of peoples which have arisen from engineering inventions and engineering industries.

Let me emphasize the fact that engineering is the tie which bridges the chasm lying between the mathematical, physical and biological sciences as one abutment and the human phenomena of economics and sociology, with their psychological qualities, and which jointly constitute political economy, as the other abutment. As a field of learning or of action, political economy is all bound up with human aspirations and passions. It is difficult to spin out uniform and sound threads of thought in its field unless and until psychologists identify and define the fundamental elements in the mainsprings of man's thinking, and then discover the principal relationships between stimulus and response. Many of the misinterpretations of the relations of engineering with present-day civilization arise because so little is factually known regarding these psychological elements in man's thinking. It is also a fertile cause of misinterpretations that human incidents in history are not more fully and widely known.

Here is an illustration that man's innate processes of thinking and acting change very slowly: What better description of the qualities exhibited in the ravishing of Austria, Czecho-Slovakia, Poland, the occupation of

Denmark and the attempt on Norway than the following: "... that bitter and hasty nation, which will march through the breadth of the land, to possess the dwelling places that are not theirs. They are terrible and dreadful: . . . They shall come all for violence: . . ." This might well have been written in the year 1940, but in fact, it comes from the Old Testament book of Habakkuk, which is supposed to have originated about 2,400 years ago, and the nation referred to is definitely named as the Chaldean. The quotation is a transcript from the King James translation, which was first published over three hundred years ago. There is no suggestion or inference in the trenchant charge against "that bitter and hasty nation" that it was enabled to carry on its violent career because the development of technology had outrun utility, as the charge is made against us to-day.[2] It is obvious that man (both individually and collectively) has not yet become convinced that a life of honesty and fair dealing is more profitable in the long run than the reverse. An apparent profit of the moment still looms larger in most human eyes than the dribbling profits of the long run. Here is a great field of education crying for the attention of sociologists and philosophers.

As badly off as we may be in this country compared with abstract possibilities, we nevertheless have reason to hold up our chins. I will quote a bit from one who should know, Louis Adamic, who himself came to us as an immigrant and who now has turned himself to the effort to awaken in us an understanding of our faults and to stimulate a more fully organized mutual effort to overcome them. Referring to the great proportion of our population who were immigrants or are in descent from immigrants, he says that the great majority of them "are humble folk, workers and farmers who skate on thin ice along the margins of our erratic economy. Some are or were on relief, though not nearly so many as generally imagined . . . . There is no doubt, though, that most of them *are economically better off here than they would have been in the old countries*" (italics mine).

It has been asserted customarily that our relatively high level of living for all citizens is due to the wonderful supplies of natural resources to which the people of this nation fell heir. But there is a catch in that. Those natural resources would not have raised our people to their relatively high level of living except for the steady application of a high level of intelligently directed industry associated with the greatest development of engineering technology through scientific discovery and invention which the world has ever experienced. We can continue in the same route and maintain ourselves on a rising level and to an improved civilization through the steady scrutiny and improvement of our engineering by farther exertions in the field of scientific discovery and invention; and with that rests our salvation as a people. Relatively, our ethical and altruistic status has been good, but in absolute measure it has much progress to make.

[2] The cynically brutal violation of Belgium and Holland has occurred since the date of this address. The analogy with the barbarous Chaldeans is not lessened.

Before turning to our part as engineers in the great problem of our responsibility previously referred to, I will speak of one other factor. Some 2,000 years ago there was put before the world with astonishing boldness, vigor and vitality the ethical tenet of the brotherhood of man, in the preachings of Jesus Christ which established the doctrines of the Christian religion. The doctrine of the brotherhood of man stands to the front in no other world-religion. It has been thought of as a guide in the western world, with its full adoption to be expectantly worked for. We now know that the expectation has been over-optimistic, for the tenet has not secured a firm hold among certain of the peoples of the world even in the Occident. However, the vitality of the doctrine is proved and its qualities impose an additional responsibility on the followers of engineering—and especially on those of us who live in America, where our substantial freedom of thought and effort is established.

Let us now think of what engineering education is—and why it is. Mathematics, chemistry, physics are largely analytical; political economy is still largely in the classification stage of development; engineering (including invention) is synthetic in the ultimate, because it builds up by transfusion the scientific processes into human welfare. Engineering and civilization originated in an association with human welfare, and both continue to exist because of this continued relation with such welfare. We must accept the fact or we are not fully qualified engineers. As the poet Horace says, "The grape's in the raisin." We can not dodge the fact.

Engineering education has for its purpose the provision for its students of knowledge and wisdom in certain fields. This requires a reasonably successful effort on the part of the students to become filled with a knowledge of facts of nature and their relationships, and with facts regarding man and his relationships, and to become wise in adapting the phenomena of nature to the service of man. Thus stated, the total field is seen to be illimitable in its scope, and individual students choose defined portions in accordance with their tastes. In the early days of formal engineering education, the situation was relatively simple, because so little of the total scope of engineering was as yet drawn into an intellectual discipline or a series of such disciplines. Most of us then expected to deal with structures or means of transportation, or perhaps both, and the relations of these to public welfare were quite definite. But we now have a series of disciplines amongst which each student chooses that which he prefers to follow in a major way; the activity in scientific discovery and invention has resulted in a vast scope of engineering industries, for which the relations to human welfare are no longer definite; and study of these relations has become a compelling part of engineering education.

It is here proper to introduce the reminder that stale minds do not come to greatness in engineering any more than they do in poetry, music or art; and the engineering teacher who is commonplace in his teaching of engineering topics is merely opening to his students the entrance gate to the broad highway of mediocrity. Engineering is of the intellect and engineering education in its higher development must be an intellectual education—but cultivation of the imagination, associated with the quality of "carrying through" projects concretely, is a *sine qua non*. The inventor-genius of American engineers has held a great part in the development of a high level of living in the country and it continues in its good effect. This should not be forgotten in planning engineering education. Here is a frontier which can not be pressed back or exhausted while American intelligence is maintained, however actively the exploitation of the frontier's figurative forests and the turning of its figurative sods are carried on.

3. How We Are Meeting Our Responsibilities to Society

From the foregoing, it is easy to see that we are resting in a situation where the engineering schools have special responsibilities because education is not a thing in itself but it is, if properly visualized, for each individual a preparation for living in the setting into which his ambitions lead him. That means that engineering education must be aimed at a sound scientific foundation for engineering, accompanied by an adequate understanding of the influence which progress in engineering exerts on the life of each student and his fellow citizens. We have a nation in which it is intended that men may independently enterprise, build and produce to their own benefit, but with due consideration to the welfare of their fellow citizens and their fellowmen throughout the world. For this environment the engineer must be strong in his character; and for the purpose he must not only have knowledge of nature's phenomena and the characteristics of men, which lie at the heart of engineering, but he must observe acutely, think accurately, express his thoughts both honorably and cogently, and understand and interpret the truth or untruth in the expressed thoughts of others. In the early days of engineering education, the technical aspects were mainly thought of—and the engineer who came to influential place in the profession was compelled to learn the rest mostly by experience. Happily, the trend of engineering education during the past twenty-five years has brought these latter aspects into the realm of the formal educational processes, while the exact details of technical practice have been left more largely to the school of experience. Thus we have recognized a responsibility to society, the depth of which has affected our professional attitude.

If we add to the foregoing a sense of wise tolerance for conflicting views which are sincerely expressed and not logically controvertible, we have reached the scope of a truly liberal education. It is one which responds to the definition of the poet Milton (given in his "Essay on Education") that a complete education is one which fits a man to perform "justly, skillfully and magnanimously" within his sphere. The importance in the affairs of society of this last-named feature of tolerant consideration of sincerely expressed views of others has of recent years, it seems to me, become more strongly impressed in all scientific circles, including engineering; but we can serviceably give more thought to its emphasis in engineering education. It very likely is in the selection and training of teachers for important places in engineering education in which this emphasis should primarily be placed. Of the young teachers we may well say that when the tree is of good root, the fruit will be good. But, to secure the best, the tree must be properly cultivated and sprayed.

However, the responsibility of engineers to society can not be fully met by teachers alone. As the poet Horace said, in effect, of responsibility for hospitality, "No matter how good your wines may be, you must also be sure that you use a high grade of oil on the fish"; and we must get our students to reflect on the economic and social implications of engineering, without lessening their mastery of the scientific relations. The tendency for solving this problem in engineering education is to put more responsibility on the individual students for specific and general study within their chosen fields—with sympathetic direction and supervision by members of the teaching staff. This puts, within limits of a prescribed scope, the degree of responsibility on the students for their self-education and enables each one to go as far within the particular scope as he can and will. This may sound to some ears like an exhibition of unfair partiality, but we must remember that the oak and the palm require different qualities of nurture in order that each may grow to its greatest prosperity and fruitfulness; and that each one, though different from the other, is of value in its individual degree.

Examinations determine whether each student has achieved at least as much as some assumed minimum. Those who can not achieve the minimum are not altogether without merit; and fair play requires that they should be aided in the effort to enter a more appropriate channel. A few engineering schools have awakened to this fact and are utilizing vocational advisory measures for this and other purposes. Common sense consists in seeing things as they are—and this attitude responds to the sentiment of fair play. The elimination of the shallow-minded from among the pursuers of engineering education is an economy; but, principally, it is desirable for the avoidance of over-cultivation which causes mental sterility like the sterility of sub-marginal land which has become exhausted from over-cultivation. We can not afford to be unsympathetic or snobbish in the engineering schools. Our field includes applications to general welfare of the teaching of science and experience; and we may remember that a deep fault of some peoples has arisen from the attitude of powerful educated groups who have sneered at the weakness of the masses and opposed their rise. Our attitude ought to be one of sympathetic aid toward directing each individual into an environment for which he is fitted. Engineers in practice must deal with tremendous numbers of people who are incompetent to substitute in their work, but whose own work is highly needful to the success of theirs.

Some educators argue that special sectioning for classes and special provisions for the more active-minded and sound-thinking students are objectionable because they do not comport with democracy. However, this is a false argument. In no society are all people alike, whether the society is democratic, aristocratic, totalitarian, communistic or what not in form. In a democracy all people should be established in equality of rights, but likeness in quality of mind and ambition is not to be had. The problem in democracy is to enable each individual to achieve to the extent of his ability the practical benefits for himself and the body politic. Intense regard for the very best accomplishment available in an individual is the touchstone for establishing a good reputation. As a consequence, special sectioning of classes in the engineering schools, according to the mental-speeds and abilities of the individual students, is truly democratic.

Moreover, it is just and right that engineering students should exert the effort for self-education, because the benefit accrues to them individually, as well as to society. If each one of us here will reflect on the status of those who are outstanding among his associates, I feel sure that he will become convinced that in most cases concentrated self-chosen study and keen observation of the consequences of experience are the foundation of the elevated achievements. Engineering students should learn in the engineering school, if they have not learned it before, that the moment one quits in the effort of self-education and demands to "be taught," one simultaneously turns one's back on one's individual progress in the profession; but that, as long as one studies and gains additionally the benefits of life and experience, one may expect the efforts to be rewarded.

Happily, these principles are gaining stronger hold among the engineering teachers. Conventional, pedantic and treadmill practices are losing fashion in the engineering schools, pre-digested text-books are not so widely popular as formerly, and the encouragement of independent student thought and effort is more in the style. Easing of the load of conventional class-hours of work assigned to the teachers is needed in many institutions; and advantage would be derived thereby for students and for the engineering profession—even though the result should be that fewer engineering details are dwelt upon by the curricula. A wider use of the exchange of professors among the engineering schools would be helpful in accelerating this reform, by broadening the bases of experience enjoyed by individual teachers.

Most of us here are engineers and teachers of engineering subjects. We thus are bound in two professions—engineering and pedagogy. Engineering is a research occupation which holds our hearts' interest, but we have come to appreciate the importance of sound pedagogical reasoning—or we ought not to hold our posts of teachers. We also have come to a lively appreciation of the importance in engineering curricula of the arts of expression (*i.e.*, the languages and drawing) and of political economy which comprises economics and sociology, because of the important part that the utilization of the former plays in every influential man's life, and the tremendous effect that engineering plays, and has played, in the economic life of the nation and the development of the national, social and political life. We also appreciate the desirability of acquaintance with recreational fields of the nature of music and art and literature.

As engineers, we are jealous of our mastery in our particular engineering topics and, as good teachers, we wish to teach and inspire within their boundaries; that is, on ground which we know best and in areas within which our inquiries may be most interesting to us and fruitful to the nation. We understand the importance to our students of becoming skilful in the arts of expression and qualified in knowledge within the field of political economy, and we ought to insist that only masters in those fields should be drawn upon to teach those tenets to our students. We ought not to desire to ourselves control the teaching of these subjects, because they are not of our mastery and the topics of our own mastery ought to hold us each individually bound.

In this we have been hesitant and have failed to lend full sympathy and encouragement to the teachers in these collateral fields. Indeed, these collateral departments often have been looked upon as ones having nothing more substantial to offer in our educational setting than a rather thin criticism. As a matter of fact, it would be good for all concerned to invite them to prove their interest in solid contributions to education for fully rounded professions. This more sympathetic attitude by the engineering professors toward the collateral departments appears to me to be gradually expanding—but it is worth while to emphasize the lesson of hearty cooperation of all departments for general benefit and for the best interest of overlapping features of the work, remembering that cooperation connotes friendly concurrent effort by a multiple of individuals.

Respecting purely recreational topics, we all recognize that substituting evanescent material in an undergraduate curriculum in place of substantial basic studies is like substituting second-rate concrete in an edifice where only marble is appropriate. However, there are certain features needed to support our work, and happily it is common observation that students in the engineering schools that are located in large cities take general advantage of the excellent opportunities to hear fine music and see great art; and interest in their doing so is expressed often by members of the engineering faculties. It is my inference that the radio carries much good music to engineering students in engineering schools located in the lesser cities. Optional studies now are available for stimulating these interests and interest in literature as well as world interests.

And now I imagine that you are bursting with the question, Why should engineers be held responsible for guarding their work from diversion into paths which are harmful to civilization, while research scientists are not held responsible for making useful applications of their discoveries?

The statement of the question shows the answer. Engineering is the art of directing the forces of nature for the service of man—and any diversion to disservice is false. We may condone a cloistered attitude on the part of research scientists, although we may regret the withdrawal of able men from reflection on the duties of citizenship. But engineering is as deeply involved in the economic aspects that arise from it as it is in the scientific aspects from which it springs. As individuals we can not control the misuse of our works, but it is a duty of the engineering schools to impartially expound to their students the various economic and social influences that may arise from engineering. We need more clearly defined research into the serviceable and the disserviceable effects that may arise from engineering which springs out of scientific discovery and invention, so that the great populations of the world may better know how to avoid the disserviceable.

In the meantime, it rests with the engineering schools to put before their students the truism that untoward events arise out of human errors, angers, jealousies, vanities, selfishnesses and greeds; while fortunate events arise out of the developed sense of mutuality of interest among individuals and nations—which sense leads to platforms of generous fair dealing. Here is where we are now most deficient in our efforts. The problem of improvement is a difficult one, but I have seen such magnificent improvement in engineering education during the last half-century that I am filled with the optimistic belief that this problem ultimately will be solved.

OBITUARY

JOHN ELIOT WOLFF

The death of Professor John E. Wolff brings to an end a close association and friendship of more than forty years which for the writer of this note has been a major influence in his scientific work. Our acquaintance began in 1895 when he called me to Harvard to help in the reorganization of the mineral collection of which he had recently been made curator. Wolff was conducting courses in petrography and mineralogy in a newly organized department closely associated with the department of geology. Instruction in mineralogy was within a few years placed in my hands, and Wolff devoted himself to petrography and optical mineralogy. His interest in the Mineralogical Museum grew with the years, and he gave a large portion of his time to its improvement. He added to it largely from his private means since it was not at that time endowed. He also provided instrumental equipment for the laboratories and equipped a chemical laboratory where he did quantitative work of great accuracy.

Wolff studied with Rosenbusch in Heidelberg in 1884–85 and was one of the first to teach in this country the then recently developed science of microscopical petrography. He was much in the field in his earlier years: with Shaler in Kentucky; with Pumpelly in the Transcontinental Survey for the Northern Pacific Railway; and as a geologist of the United States Geological Survey, working in western Massachusetts and northern New Jersey. His name appears as co-author with Pumpelly of the monograph describing the Hoosac Tunnel section through the Berkshires, he having done the optical petrography as well as much of the field work for that study.

He took part in the International Geological Congresses of 1900 in France; of 1906 in Mexico; of 1910