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INTELLECTUAL INTERCHANGE AMONG FACULTIES OF ENGINEERING SCHOOLS[1]

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A MAN who becomes over-trammelled by rules, precedents and tradition will always remain a commonplace man. One who breaks precedents and tradition seldom is a commonplace man, and from such usually come the helpful leaders or notable criminals. The ones who break conventional rules with convincing service to fellow men and without injury to the social organism are the leaders. An instinctive ability to recognize the times and places when usual conventions ought to be observed, and when progress may be better achieved by breaking their shackles, is evidence of originality and creative vision. These qualities should be more fully cultivated in the faculties of engineering schools, and their evolution made a matter of our earnest mutual concern.

It is interesting to reflect on the erroneous conventions and traditions which came to us from the Victorian era and which have biased the thinking of the present generation. For example, it is still sometimes individually believed and taught (because of Victorian tradition) that the Periclean period in Athens was the golden age of the world. Nevertheless, it probably was the orgy of exploitation and spending by Pericles and his party which brought ancient Athens to the brink of its downfall with resulting increase of sorrow and hardship for all the population, from the highest citizen to even the lowliest slave. Thinking of that period as a golden age for humanity, whatever its triumphs of sculpture and architecture, exhibits a failure to inquire and explore beneath a surface aspect which is deceptively polished and graceful. This deficient procedure is not appropriate to education which is to serve for the best interest of civilized society or its individual human components.

[1] Address before Society for the Promotion of Engineering Education, in Engineers' Week, Chicago, Illinois, June, 1933.

In our level of engineering education, and perhaps in all levels, teaching that is instruction without having associated with it the spirit of inquiry is bad pedagogy. That is, the practise of research is a vital part of engineering education. But research which is carried on in guarded chambers to avoid student contacts does not contribute to educational processes and may not be appropriate to engineering schools, although its discoveries ultimately may contribute to social welfare. Similarly, educational processes almost always become conventional and unvital if the processes are prevented from securing infusions of ideas from outside, whether this prevention is due to lack of enterprise or to intent.

Perhaps engineering education, being established in an expanding and interestingly changing field, may be less subject to devitalization and conventionality than education in some other fields of learning; but we all are aware nevertheless of the ease with which teaching can become conventional or even perfunctory. It particularly rests with those who work in the expanding and inspiring atmosphere of applied science to avoid conventional and uninspiring processes. Out of this concept springs another element in the importance of maintaining constant interrelations between all engineering school faculties and of making interchanges of studied views on educational problems.

The distinguished accomplishments of this society through its Board of Investigation and Coordination and other committees, in expounding the trends of engineering practise, the processes of engineering education and the character of personnel appropriate to teaching staffs for the engineering schools, lay upon us who are in the teaching ranks a peculiar and exalted responsibility to make the most of opportunities that are thus shown to be within the reach of our hands. Reports of our situation and suggestions for procedures are definitely before us. It is for us as individuals and as faculty groups to bring farther fruit from the vineyard thus planted.

Professional distinction in the engineering field is supported on wise vision of the profession concerned, sound and independent judgment and deeply rooted learning. This calls for talent, and it also calls for industry, energy, originality and resourcefulness. The slavish follower after habit and tradition is sure to be left behind in this, as in any other, creative employment or profession.

Engineering is an affair of human welfare and those employed in engineering education must bear this in mind. Seekers after romance who "stand knee-deep in indolence" can not rise to the high offices thrust upon a correctly chosen engineering teacher. Intellectual indolence is an irretrievable fault in any such. We conceive the life of the engineer as a high calling, and ask others to so conceive it, because (among other things) all those spiritually impelling activities which afford us means of distant transport of body or intelligence from place to place and from person to person are engineers' contributions to civilization. The railroad, the steamship, the highway, the telegraph and the telephone provide statesmen with instrumentalities through which the substantial kinship of all the world some day may be established. Electric transmission of power and artificial lighting contribute substantially to ease and comfort in civilized life. Still fuller cooperation among applied scientists may yet become one of the wonders of the world and out of it arise benefits to mankind as yet undreamed. Even the health of individuals may become completely safeguarded by discoveries made possible by the joint application in the medical field of the learning of physiologists and the accurate instrumentalities for measurement which spring from the learning of engineers.

These illustrations point to the fact that further engineering achievements need not be assumed to be limited solely to improvements of existing instrumentalities utilized by society, but may be visualized as also including additional influential discoveries and inventions. With the development of civilization and its accompaniment of an organized society possessing protective agencies guided by the hand of a definitely established central authority, instrumentalities for communication between individuals and between communities take the place of instrumentalities of exclusion. Thus the building of walls to surround living places with intent to prevent enemy ingress but which also result in a decrease of mutual access between friends has ceased in the present era and the building of roads which increase access between peoples and contacts among the individuals has become widespread. Such great changes in living conditions (of which there are many), and equally great changes in the level of civilized thought, result in corresponding changes in the aims and the achievements of education.

The utilization of natural forces for the benefit of mankind has been the result of engineering originality and resourcefulness continued through the entire period of recorded history. The first such utilization presumably arose from crude observations of natural phenomena by some independent-minded person with curiosity and a love of economy, that is, an inventor, who was thus in a single embodiment the original scientist and the designer of the applications. Many ages afterward there came a period in which research in science became an end in itself, thereby bringing additional precious facts to the hands of engineers in addition to those which the engineers themselves had time to detect. Now we still farther develop this

specialization between the so-called pure scientist and the engineer or applied scientist; and we also combine the two functions, in coordinated fashion and in the hands of combination groups, for seeking out new facts and discovering new applications.

In order that mankind may be guided to use most desirably the great powers now at its command as the result of the applications of science, it is needful for engineers to inform themselves in the principles of political economy and psychology, in addition to the principles of chemistry, physics and mathematics which are universally recognized as part of an engineering curriculum. These principles of political economy and psychology which are studied ought to be just as fundamental as the principles of the older sciences, but unhappily they have not yet been so formulated. Progress in this direction for political economy perhaps has been delayed by the fact that many of its teachers have sought the life of contemplative philosophers, while political economy is a dynamic entity associated with the changing social organization and therefore must be studied from the applied, experimental aspects.

Engineers carrying forward the front of applications of new discoveries are dealing with a growing field, full of changes, which can not be mastered wholly through philosophical bookishness and contemplation. However, they are not fleeing from the past like the family of Lot from Sodom and Gomorrah. A backward review from time to time, of comprehensive but brief nature, produces good results in the way of evaluating progress and improving the accuracy of foresight, but we must also remember that too constant an eye on the past produces results which are as incurably useless as the pillar of salt in the alkaline desert into which Lot's wife was transmuted because of her backward longings.

Resourceful empiricism in life belongs to the days of the youth of the exact sciences or of education or of a new country with a pioneer population. We have these conditions all as a background for engineering education in America. In our present considerable maturity we must look forward to more rational bases of reflective life and of reasoning, but these must be secured without loss of national or personal originality, initiative and resourcefulness. Time is to-day, yesterday and to-morrow. We have for ourselves only to-day, supported by some memories and records of yesterday and some anticipations for to-morrow. Therefore in our engineering education we must emphasize modes of life and knowledge of natural phenomena as they respectively exist to-day. We should also add thereto competent reflections concerning possible improved modes of future utilization of natural phenomena and probable improved conditions of life resulting from such improved utilization.

Science refuses to be enchained, but will continue with its victorious career of expansion. It is for the engineers to see that these victories are not merely Pyrrhic. For this, our educational processes must touch, elbow to elbow, with the most intellectual expounders of principles that are established in political economy, sociology and finance, in addition to our established association with expounders of the natural sciences.

Early histories deal at length with achievements of tyrants and warriors and but little with mechanical achievements. Such records show the emphasis which was formerly placed on the welfare of the high-born, powerful and wealthy classes and their valuable slaves, to the substantial exclusion of all other orders of humanity. The shifting of this emphasis so as to rest, as it now mostly does in the western world, on community welfare, with the attention comparatively equally directed toward the high placed and the lowly, is one of the most conspicuous revolutions in social relations which has occurred between our days and the days of the ancient civilizations. The classicists are blind and misguided enthusiasts when they unreservedly extol the ancient civilizations. The cruelty and the narrowness of mental interest usually characterizing the powerful coteries in those civilizations is scarcely realizable to minds educated in the broader and more generous spirit of our times, although our times are often derogatively referred to as a mechanical age or civilization.

It is wrong to speak of a "mechanical" civilization, because civilization is intellectual and an intimate correlative or component of the social organization; but we must recognize that true civilization rests upon mechanical development which enables the spread of wealth and comfort to be effected immeasurably more uniformly than characterized the conditions of ancient times, such, for example, as were characteristic of Greece or Rome or Egypt even in the most humane stages of their ancient civilizations. Science and invention can be put to bad uses, but this does not justify engineering education in neglecting the fullest practicable cultivation of the ground from which springs the best character of modern civilization, or in neglecting to examine the characteristics of that civilization itself.

Engineering is a vital and dynamic field of learning which stretches from biology, chemistry, physics and mathematics into political economy, finance and sociology. It is not practicable for any one man to possess complete mastery over the whole field or of any one of its major divisions. We therefore assign particular subdivisions to our individual teachers in the engineering schools, each of these subdivisions being of a scope in which the individual can achieve a mastery. This meets one branch of the teacher's

difficulty, but farther provision is requisite to meet the situation fully. Each particular subdivision closely relates more or less intimately with numerous other subdivisions as well as with its own major division. Each major division relates with each other major division, sometimes with close analogies in the applicable theories, even when the nomenclature and units of measurement superficially appear to have no relations. And all the major divisions and the subdivisions have threads binding them to the natural sciences on one side and to political economy, finance, sociology and psychology on the other side. Moreover, these threads are weighted with various degrees of significance, and this brings us face to face with situations which in some instances may be dealt with with mathematical exactness and in other instances can be dealt with only through examining the balance of evidence (*i.e.*, the balance of the "pros and cons" as commended by the great Franklin).

The problem of securing proper teaching staff for the engineering subjects taught in college therefore has two branches. One of these relates to securing men with the needed learning, ambition, originality and resourcefulness to become and remain masters of their particular growing subjects, who also possess powers of formulation and exposition sufficient to establish scholarly interest in the study of their subjects. The second of the branches relates to selecting from among such men only those who individually have the imagination, ambition and initiative to unremittingly examine and reflect upon the correlations with each other of at least some of the subdivisions of engineering and also upon the specific scientific and economic roots of some particular subdivision or subdivisions.

Any teacher who secures and maintains for himself mastery in a particular subdivision of engineering becomes an investigator on account of the nature of engineering, and such a one is competent for research into the character of scientific principles, their application for the benefit of man, and the propriety of empirical processes which may be utilized where science is not yet established because of the complexity of premises. Such a man is delivered from slavery to predigested textbooks.

It will be observed that the word mastery, as here used, is synonymous with the phrase, Authoritative grasp secured from fullness of knowledge and experience.

The major question to be answered is how such men are to be secured. Various answers have been proposed, but no one of them (in my opinion) is complete. I therefore venture here to give my own, and my doctrine is here spread before you with invitation for criticism and farther test. In science, a theory which fails as a directive for further research within its province, or as a platform from which to improve designs of structures or equipment, is as worthless as the man whose wife called him "Theory" because he so seldom worked. The same is true of a theory in education.

The first tenet associated with my answer holds that experience proves that (in general) the engineering schools as a group must develop the teaching staffs for themselves and not expect to rely on other organizations, such, for example, as industries or schools of education, to develop our units for us; although we should welcome suitable reinforcements from such other organizations. The same conclusion is reached by *a priori* reasoning. This makes intellectual interchange among faculties very important. To secure what we need, each member of our staffs should strive to possess an education arising from experiences that have been secured by contacts with the cross-currents of various creative minds. Part of this should be secured in youthful preliminary education; but part of it ordinarily should be associated with the individual's early period of employment in teaching because the members of staff ought to become established before they are too old, as we need the activity of youthful originality and initiative in the engineering schools.

The second tenet is to avoid undue inbreeding. This requires an interpretation of the word "undue" to make the tenet definite. Different men of experience may ascribe different weights to it. In my opinion, inbreeding exceeding 50 per cent. in staff membership may be undue. As a teaching staff grows in numbers and scholarly scope, it is desirable to seek promising recruits from elsewhere for the purpose of maintaining a flow inward of new experiences; but it is equally needful to maintain a continuous thread of endeavor, which can be most advantageously done by choosing a proportion of recruits from one's own products.

A corollary to the second tenet, therefore, is to select appointees from the product of other colleges as often as from one's own product, and to emphasize the fact that an advantage (especially for the younger staff members) arises from migration. The recognition of the latter condition should prevail over any desire on the part of an appointing officer to hold a staff inviolate from withdrawals. An engineering school has a duty in the preparation of young men for productive endeavor in other such institutions as well as for the industries and for itself. An undue jealousy of withdrawals of competent young men from staffs defeats this duty and also perhaps indicates a lack of fertility in selecting young men and encouraging them to make a high career.

The third tenet (which is closely connected with the foregoing corollary) is to encourage young men

to study and observe in several environments. This may be through formal study elsewhere than at their normal sites of employment or by suitable industrial employment for the period of a few years or by organized study with which is associated industrial employment in vacation periods. Industrial employment in the vacation periods in many instances is equally as serviceable for men of the older and well-established ranks as it is for the younger men. The conferring of fellowships on younger members of staff, available for a year or two of serious study in a chosen academic setting elsewhere, is one of the fruitful expedients which is only too little recognized by engineering schools. Encouraging promising members of the staff to attend, in their individual fields, the summer sessions established for engineering teachers by this society, is a step in the same direction. If salaries and ambitions are right, young men should respond to this encouragement without special financial subvention, because response is farsighted thoughtfulness for personal development.

There is the further corollary that study and travel in European countries (for the American engineering teacher) have the advantage of unfolding widely different environments, and are likely to lead to sound reflection on the part of suitable young men. Individuals who have embraced such an opportunity and who fail to grasp the grounds for differences as well as for likenesses of engineering practise and engineering education on the two continents, along with some recognition of the faults of each, have been tested and found wanting and should thereupon be diverted from the profession of engineering education. As far as the facilities for engineering study themselves are concerned, America now rivals the best of Europe in substantially all branches and excels in many. Under the circumstances, the mature student who wishes to become a recognized influence in engineering education, who fails to uncover and embrace the opportunity to glimpse the ideals, the spirit and the resourcefulness of several great men who are in his chosen field in Europe or America, fails to fully utilize his opportunities for education.

The fourth tenet is to encourage teachers who wish to do summer school teaching to secure such employment in the summer sessions of engineering schools distantly located from the sites of their own winter teaching. It is my opinion that continual teaching on the same premises and among the same colleagues during the academic years and the intervening summer sessions inevitably cramps development. Staleness is likely to result from too continuous an effort of one kind carried on without external fertilization. It would be a step forward for the engineering schools to man every such summer session with a considerable proportion of teachers drawn from other institutions.

Still another means for carrying through to the same fruitful end is for engineering schools to definitely exchange younger staff members for such periods as one or two academic years. Difficulties for the engineering schools themselves arise regarding this on account of family movings, matching of living accommodations, differences of cost of living in different educational centers, differences of salaries in like ranks and other items. This plan therefore is not likely to be frequently used, but all the other plans are practicable of execution, provided the necessary incentive is impressed on the individual teachers. This society could achieve an additional forward step for engineering education if it undertook to procure the establishment of several definite exchange professorships among the American engineering schools, outside of the normal budgets of the schools, which could be conferred from year to year on particularly distinguished professors of such schools who would then lecture for a semester or two at schools other than their own.

The ideas presented herein are not academic platitudes, but are in fact pedagogical sense. They are paths of good business sense for engineering teachers to follow. To those who say that they are exalted but impracticable ideas, the answer is that they are indeed exalted ideas, and engineering education needs such ideas put in practise as useful truths. Moreover, they are of proved practicability. For example, in the large staff of the distinguished department of electrical engineering of which I have the honor and privilege to be the leader, there are few of us who have failed to embrace education and practise in more than one richly serviceable environment. This circumstance has manifestly proved to the advantage of our mutual work.

Engineering education has been endowed with its fair share of great men. We may think of Swain, Van Hise, A. W. Smith, Irving Church, Mansfield Merriman and others of their group. It now possesses a considerable proportion of such men and also of younger men with attributes that will bring them to equal eminence and influence; but President Wickenden in his final report as Director of Investigation for this society expresses a fear that the number of such men is not increasing numerically in proportion with the growth of numbers of engineering schools and numbers of students. The work of each great man is a guide-beacon illuminating the way. But his successors who sit contentedly in the shadow of the beacon without effort to progress, waste opportunity. The doctrines of academic tenure for older men and academic freedom for both older and

younger men are sometimes said to stand in the way of insisting on effective individual and group work. It is true that some individuals are unable to maintain their intellectual balance when partaking of the "strong wine of freedom," but such men are out of place in the teaching staff of an engineering school. It is a strain on the doctrine of academic freedom to retain such men unless age, length of service or laches of the institution appeal for tolerance.

Thinking with accuracy is no child's accomplishment. That accomplishment must be learned first in thinking analytically and then in thinking synthetically. Such education goes much faster when the effort is stimulated by the interest of mastery rather than when only sustained by the urge of duty. Each classroom and laboratory should be a space redolent with curiosity and discussion.

To secure the needed results it is important to utilize foresight and judgment applied through measures such as my answer comprises. All these measures depend upon developing among engineering schools a greater unity of purposefulness designed to result in a larger sentiment among their staffs in favor of migration than is now observable.

Finally, to secure the ends, in my opinion it is necessary for the engineering schools to maintain salaries in the higher levels which are equal to the highest which their universities support. Otherwise the ultimate attractions are insufficient to appeal to the fitting youths. I often hear it suggested that the upper available salary level has only small influence on the ambition of the younger teachers, but I am convinced that this is an erroneous interpretation of the attitude of the most able of our younger men. The opportunities of the life are compellingly attractive to men of suitable ambition, but the opportunities can not be most fully developed unless finally accompanied by a generous situation in support of a professional self-respect that comports with a distinguished reputation for learned mastery in the field.

A sustained effort to accomplish these ends will, I believe, maintain engineering education on an enviable level of achievement among the great educational processes of the nation.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SECTION M (ENGINEERING)

By Commander N. H. HECK

SECRETARY, U. S. COAST AND GEODETIC SURVEY

IN SCIENCE for July 28, 1933, there was a review of the scientific sessions of the American Association for the Advancement of Science and affiliated societies. For several reasons that of Section M and affiliated societies was not included, the chief reason being that it required additional time to prepare a report of the many sessions in such a way that the relation between science and engineering would be emphasized. The meetings of all affiliated engineering societies are discussed, except that the joint meetings of the Econometric Society and several engineering societies have already been described in SCIENCE under Section K (Social and Economic Sciences). Numerous other engineering societies met in Chicago, but this report includes only affiliated societies. The Western Society of Engineers, an associated society, held no session, but played a very important part in arrangements. Owing to the delay in presenting this record of the meeting many of the papers mentioned have already been published in full or in abstract. Information can be obtained in regard to these from the secretaries of the societies concerned.

The second week of the joint meeting of the American Association for the Advancement of Science and affiliated societies at Chicago on pure and applied science during A Century of Progress was devoted to applied science and, since nearly all the engineering societies took part, it was generally known as Engineers' Week, though there were numerous meetings in other fields of applied science. Section M (Engineering) was the connecting link. It held a joint meeting with all the engineering societies and a joint meeting with the American Society for Testing Materials, these being the occasions of addresses by distinguished foreign speakers made available through the association.

At the general meeting on Tuesday night, A. P. M. Fleming, of the Metropolitan Vickers Company, had as his subject "A General Review of the Development of Industry and Engineering During the Century."

Reviewing the past one hundred years of development in industry and engineering, certain considerations are outstanding. First, engineering is the basis on which the magnitude and rate of progress depends. Through the growth and application of scientific knowledge it has made the world a small place; it has increased speed of travel by road, rail, air and water; through speed of communication, it has eliminated time and distance; it has enabled the earth's resources to be made universally available; it has been the means of providing for the growth and maintenance of populations with increasing standards of living. In other directions, medical science