Ideals For Engineering Education in Pakistan

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Introduction

Engineering education as conceived and practiced today in many parts of the world is a special type of education. It is not a professional education as is education in medicine, law, and theology. It is not a specialist's education, that is, it produces no experts in a particular field of knowledge or skill. It is not liberal education, for although it has no concrete objective in sight its subject-matter is not "Life in all its manifestation" [1]. At its best, it is an education preliminary to becoming a specialist or a member of a professional group—whether an engineering designer, a manager, a research worker, a teacher, a construction specialist, or a salesman. It is a general education which may or may not be followed by a professional training or a specialist's education.

To become a practising engineer, it is not really necessary to be educated at a college. In some societies one could qualify as an engineer by passing an examination which does not necessarily require a formal engineering education. That examination one could pass by studying at home and by meeting some other stipulations for achieving a prescribed amount of experience and training. In some other societies one could practise as an engineer by virtue of having been admitted to the membership of a recognized professional organization, for which again no formal engineering education is a prerequisite. There are still other socicties in which one could practice as an engineer simply by virtue of his experience and competence in the profession. Thus, the term engineering education as it will be used in the following pages shall not necessarily refer to an acquisition of engineering knowledge or skills, although they constitute an essential part of it. Rather, it shall refer to the formal education and training which is generally given the title of engineering education.

The aims of contemporary engineering education are (1) to train a technically competent person, and (2) to develop in the student character, ideals, and culture—that is, to impart education for well roundedness of he student's personality.

EDUCATION FOR TECHNICAL COMPETENCE

In making a study of the aims of engineering education for technical competence, as practised in foreign countries, particularly the United States and the United Kingdom, one notices a great semantic variety in which the institutions prefer to state them. Different colleges speak of the education they impart in different ways.

> The Massachusetts Institute of Technology [2] aims at preparing . . . young men and women to accept . . . the challenge of opportunities of professional leadership.

This means that the institution aims at instilling such technical ability and professional competence in its students as will enable them to play a leading role in their profession. The statement is quite a general one. A medical college, a law college, or any other professional college would probably be glad to state the aims of its education in the same terms.

> At the California Institute of Technology [3]
> The primary purpose of the undergraduate school is to "provide a collegiate education which will best train the creative type of scientist or engineer so urgently needed in our educational, governmental, and industrial development."

The Cornell University bulletin [4] refers to an educational program that aims

> ...to train beyond ordinary competence in practice of the profession and to develop the qualities that foster growth and leadership in future years.

The Engineer's Council for Professional Development [5] seeks to spell out the aims of an engineering education and states them in another language. It looks for

> ...the extent to which a curriculum develops the distinguishing characteristics of an engineer—*ability to design*, recognized in its broadest sense by the Committee to be 'the ability to apply creatively the 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...'

This quotation, unlike any other that has been mentioned before, speaks of the qualities of an engineer in abstract terms.

Comprehensive statements of the objectives of engineering education have also been made from time to time by the American Society of Engineering Education.

The Calendar of the Imperial College of Science and Technology, London [6], sounds yet another note. The purposes of the college as stated therein are

> ...to give the highest specialized instruction, and to provide the fullest equipment for the most advanced training and research in various branches of science, especially in its application to industry.

Some other colleges in describing the nature of their educational program go even a step further—these colleges do not claim to impart specialized instruction, nor do they specifically refer to such aims as training for citizenship or training for a professional career. For instance, Harvard University [7] merely speaks of providing a

> ...broad coverage of the physical sciences which are a basis for subsequent professional studies in any branch of engineering or applied science. The program is especially suitable for those who wish to pursue careers in scientific research, development...

A similar line may be found in a description of the Engineering Honours School at Oxford University [8], This school

affords scientific training in principles which form the foundation of engineering...

There are, to be sure, other ways of stating the aims of engineering education than the ones that have been cited above, but these are sufficient to point out the difficulties that arise in interpreting them and comparing them with one another. The aims as stated by a school in terms of the subject-matter taught and the training given cannot well be compared with the aims of another school which states them in terms of inculcation of responsibilities for citizenship in a social order.

To recapitulate, the technical aims of engineering education as stated by the various engineering colleges and societies are to produce a person who : (1) is technically competent to face new problems with skill, initiative, and leadership, and with an appreciation of the economic factors involved in such problems ; (2) has a desire to progress professionally in the direction of research, development, design, construction, sales, or education, with the motive of making distinctive contributions to the welfare of society ; (3) is a mature thinking individual with an appreciation of social values ; (4) has ability to organize thoughts logically and express them lucidly and convincingly in written and oral English.

An examination of the aims indicates that the engineering educators, in the first place, are inculcating in the student a certain technical competency. He is being prepared in the classroom to be able not only to solve the familiar but also to attack the unfamiliar problems that continually arise in the field and design office. Moreover, the engineering educators recognize the economic importance of the engineering enterprises and, therefore, aim at inculcating an appreciation of the financial side of the engineering endeavors. Further, the engineering educators feel that, unless they have been successful in instilling in the students a desire to advance engineering knowledge, to improve its methods and techniques, and, as members of a professional group, to dedicate their services to the well-being of society, the task of engineering education is not completed. These are the main aims with regard to the technical side of engineering education.

EDUCATION FOR WELL-ROUNDEDNESS

Contemporary engineering education is not restricted to the training of merely a technically competent person. Indeed, it is aimed at much more. The Massachusetts Institute of Technology [2] speaks of preparing

> ...young men and women to accept the responsibilities of citizenship in a democracy...

The Imperial College, London [6],

> ...attaches due importance to the encouragement of board interests : to the development of those human qualities that contribute to...a liberal view of life.

According to the bulletin of the California Institute of Technology [3]

> ...every effort is made in the undergraduate section of the Institute to carry on a well-rounded, well-integrated programme which will not only give the student training in his professional field but will also develop character, ideals, breadth of view, general culture, and physical well-being.

These statements typify the aims of the rounding out of engineering education. Usually engineering educators describe these aims in a very general language. What constitutes "character", "ideals", "general culture", and "liberal view of life" is not specifically defined.

The difficulty of precisely defining the specific aims of the rounding out of engineering education perhaps lies in defining what constitutes a good life, for proper character, ideals, culture, and other virtues must be a part of the good life for which an engineering student is being prepared. But if it is not this difficulty that keeps the engineering educators from elaborating

the aims, then perhaps they might feel that a concept of a good life is a thing so obvious that it needs no specific elaboration. Whatever might be the case, the engineering educators seem to assume that the engineer of to-morrow will be living in a society based on sound moral and spiritual principles. The student is encouraged to learn about the themes and the concepts on which the social and political systems of his society are based. The underlying idea seems to be that if an individual is aware of the principles and beliefs at the back of the current standards of right and wrong, then he will through his own light be able to conduct himself in this world without accepting the commonplace notions blindly.

Furthermore, the engineering educators believe that the life of the engineer of to-morrow will be loaded with responsibilities, and that each citizen and each member of a professional group will be required to perform his share of duties. They recognize the vital role of an engineer in modern society and feel that the student should learn to serve society diligently and selflessly. He should not indulge, when he has graduated, in any professional activity that he knows not to be in the best interest of society. His role as a citizen may range from casting an "intelligent" vote to leadership in the civic affairs of the community.

Besides his own professional field, it is believed that a well-rounded education should help develop in an engineering student a sense of appreciation for works of great artisitic merit in the fields of literature, music, painting, sculpture, and architecture. The following is an excerpt from a message written for the students of North Carolina State College, Raleigh, N. C. [9], as an introduction to a course in "Contemporary Civilization", which is typical of the general attitude of engineering educators :

> Finally, your professional life and your life as a citizen will occupy no more than half of your time. You have your life as a member of a family and as an individual human being to consider. The half-educated man is bound to lag behind in the pursuit of happiness because the number of choices open to him is so limited. You have a right to expect that your education will open up for you new and more mature forms of enjoyment, that it will help you to discover the pleasures and satisfaction to be derived from good reading, from painting and music and dramatics, from good conversation and from creative work of all kinds. Courses like this one are designed to help you to achieve these things.

In the United States of America there has grown a tradition to speak of an engineering degree curriculum in terms of scientific-technological

and humanistic-social divisions. The former refers to studies in subjects such as physics, chemistry, applied mechanics, and thermo-dynamics, while the latter refers to studies in the humanities, social sciences, and natural sciences. The so-called humanistic-social study is designed primarily to attain the end of well-roundedness at a formal level of education. To think of well-roundedness is to think of courses in the humanities and social sciences and *vice versa*. As commonly proclaimed, the basic aims of such an education seem to be :

(1) To transform the knowledge seeker into a seeker after truth.

(2) To point out to the student the direction in which truth may lie.

(3) To impart information about the social order in which the student lives in order to help him to live in it intelligently and usefully.

THE PAKISTANI NEEDS

The best interests of a nation are not served by copying the educational system of another country or by adopting its goal of education as her own. Pakistan has her special needs which are far different from those of other nations. It is desirable that Pakistan should develop her own engineering educational system and policy and keep it up-to-date as the situation demands. It is, therefore, necessary to survey in some detail the basic needs of Pakistan in terms of various types of engineers and the knowledge and training required for each type.

By far the largest block of our engineering graduates are employed in maintaining and repairing the existing engineering structures. Unfortunately, these are the ones who are notorious for having no use for that engineering knowledge and skill which is imparted at our engineering colleges. It is not infrequently, that one meets former graduates who have been employed for a considerable length of time and who confess that they have not opened an engineering book after leaving the college. They say that in actual practice "one does not have to be an 'engineer' to be able to serve in the 'Department'. For this apathy towards engineering knowledge the society in general and the public exchequer in particular have to pay year after year an increased price of maintenance and repairs of engineering structures. If engineering knowledge is properly utilized by this group, it is bound to result in a tremendous saving of the society's effort and money.

The next large group of engineers, although their total number is small compared to the number of maintenance men, is that which is

employed on construction of engineering structures. Men in this group, have shown in the past high administrative qualities and organization skill. Without these abilities the enormous post-independence record of big construction in Pakistan would not have been possible. However, when all has been said in their well earned praise, it must be mentioned that we in Pakistan lag far behind in technical control of engineering construction, which means that we do not get the best out of men, machines and materials. If the field control of construction were better than what it is, it would surely be possible for our design engineers to bring down the abnormally high "factors of safety" and to raise the figure of low stresses that they now-a-days assume in designing structures. It is surprising that in a country where the number of engineering structures is so large and where the rate of construction is so heavy as in Pakistan, which facts under ordinary circumstances should result in sufficient accumulation of engineering experience—a structure can be reckoned safe only when it has been made so massive as to become extra safe. This of course is done at a high price. Where there is already a shortage of capital and material, when the possible savings which can be affected out-of the initial construction are not made, the national economy suffers, a loss which can be ill afforded.

By not having engineers with that sound theoretical background which the modern production standards demand, we pay a still heavier price in the realm of industrial production. No amount of measures taken from outside the plant—of helping the industries by controlling raw materials, by affording tarrif protection and through other economic measures—are likely to solve, ultimately, the problem of high cost of industrial production in Pakistan. The bottle-neck in holding our own against foreign competiton lies and will contiuue to lie in industrial efficiency.

All over the world the design engineers form the brain of the profession. Even a slight shortcoming in their work has serious consequences. The Profession, therefore, has set for them very exacting standards of performance. In Pakistan, design engineers hardly exist as a class. In the Government services the potential design engineers are shuttled back and forth between the maintenance, construction and administrative jobs for one reason or another. At one time, the average design experience of engineers working in the large design offices of the Irrigation Branch was hardly nine months whereas in a multi-million rupees spending department as the Irrigation Branch is it should have been six to seven years with the top officers having spent most of their

service in the design office. Such a state of affairs is not peculiar to the Irrigation Branch alone.

The design engineers are expected to keep abreast of the latest development in their field. They have to learn more and more accurate and quicker methods of designing. Through the application of new methods and new techniques it is not unusual to save a few million rupees on large construction if the design engineers were given time to study various possible designs of a project and then to select the most economical one.

The class of engineers that require the highest in academic knowledge is that of teachers and research engineers. As research and teaching go hand in hand, one may speak of them as a single group. Research engineers and first rate engineering teachers are non-existent in Pakistan at present. This fact is most unfortunate. In the absence of research, the flag of advancing knowledge remains unhoisted. The teachers continue to stand in the rear ranks and consequently much remains to be desired in the knowledge of their students.

From an examination of the above it will be seen that these needs —of maintenance engineers, construction and production engineers, design engineers, teachers and research engineers are not peculiar to Pakistan. Other countries also need the same kind of engineers. However, what distinguishes the needs of Pakistan from the needs of a developed country is the fact that post-education conditions in Pakistan are widely different from those prevailing in other devleoped countries. In those countries there are sufficient opportunities outside the college for a graduate to complete his training before he becomes a full engineer. The design offices, construction projects, the industry and the research laboratories in foreign countries have in their service men who, by long experience, training and research have acquired eminence in their fields ; and these men are in a position to train younger men properly. The period of education at an engineering college there, is, therefore, limited to a minimum. In Pakistan highly qualified men in the field of theoretical knowledge, design and production etc., are non-existent. The few that are there are too busy to train anyone else. It falls therefore upon the engineering colleges to do what they can in imparting instruction in such a manner so as to minimise the effect of this handicap.

THE IDEALS OF TECHINCAL COMPETENCE

Having surveyed the needs of Pakistan in terms of engineers, a role for engineering education in the country in the field of techincal competence may be suggested. In recommending a policy it must be

borne in mind that where there exists no tradition for research first class research centres cannot spring up over-night. Where the standard of under-graduate education is still not up to the mark, post-graduate education cannot come in full swing at once. Yet it is imperative that a beginning must be made. Pilot projects must be started. Nuclei with potentialities of expansion and development must be established on the right lines.

The Degree course.

It is suggested that the bachelor's degree in engineering science should continue to constitute the minimum qualification of an engineer. The object of the degree course should be to educate and train a man for the following minimum qualifications of a maintenance engineer.

The necessary technical qualifications of a young "maintenance engineer" are, that :—

(*a*) He must have a thorough grasp of the fundamental scientific laws and theories on which his branch of engineering is based. He should understand the significance of the mathematical relationships, should know how these are derived from basic concepts and should be aware of the difference between the ideal situation embodied in the laws and the actual reality.

(*b*) He should have knowledge of advanced mathematics to enable him to understand the contemporary engineering literature.

(*c*) He should well understand the engineering properties of the common materials.

(*d*) He should be able to determine the degree of accuracy required in measurements and calculations and to make approximations accordingly.

(*e*) He should have complete mastery over the economic and engineering aspects of small scale constructional and maintenance operations. This involves a thorough knowledge of the specifications, of the engineering control of construction and of the tests that are made to check the results of construction. This also involves his ability to observe the motions, acts and performance of men and machines, evaluate their economic implications in the interest of reducing costs without impairing the strength or safety of structures.

It is obvious that with such a B.Sc. Engineering degree a young graduate just out of the college will not be in a position to take up the job of a maintenance engineer either in industry or in a government department. However, it is presumed that it is the duty of an employer to acquaint the new hand with the problems of the applied engineering science peculiar to his employment.

Courses in constuction Egineering.

The necessary technical qualifications of a young engineer who, ultimately, is to take up responsibility of a construction or production engineer are that :—

(*a*) He should have the qualifications (*a*) to (*e*) mentioned under the qualifications of maintenance engineer.

(*b*) He should be familiar with the modern methods of quality control, time and motion study and of putting to most efficient use men and machinery.

(*c*) He should be fully conversant with the working of field laboratories and of control of quality of construction in the field.

For the training of construction and production engineers, it is suggested that special courses should be arranged at the colleges to which young engineers who have acquired some field or shop experience and who are recommended by their employers should be admitted. Inevitably, such courses will have to be closely co-ordianted with the needs and working of the government departments and industry. Courses can be arranged for all large scale constructional and productional operations such as concreting, constructing high earthen embankments, surveying, material handling, road making, labour management, working of heavy equipment, quality control etc., etc.

Training of a Design Engineer.

The necessary technical qualifications of a design engineer are that :—

(*a*) He should have the qualifications (*a*) to (*e*) mentioned under the qualifications of a maintenance engineer.

(*b*) He should have mastery over the theoretical side of his design speciality.

(*c*) He should have experience of construction.

(*d*) He should have training and experience in a design office.

For the training of design engineers a post-graduate degree with the knowledge of advanced Mathematics is absolutely essential. This means that post-graduate classes should be opened at the Pakistani Colleges with the minimum of delay. Once a young engineer has completed his post-graduate work in his special field of engineering design it would be necessary for him to alternate in a design office, and in a construction job in the field before settling finally into the job of a design engineer. It might be necessary to send some prospective design engineers to foreign countries for training and education in those advanced subjects which have not yet been introduced in Pakistan such as Pre-stressed concrete, photo-elastic methods for stress determination, analysis of the phenomena associated with unsteady motion of fluids, solution of problems of soil mechanics as applied to cohesive soils and numerous other problems in the field of mechanical, electrical, chemical, metallurgical, and electronic engineering.

Research and Post-graduate education.

The necessary qualifications of a teacher and research engineer are that :—

(a) He should have the highest academic qualification.

(*b*) He should be actively engaged in research.

(*c*) He should have contact with the fields of design.

(*d*) (For a teacher only). He should have teaching experience.

For the training of teachers and research workers the engineering education in Pakistan can play but only a very minor role for the present. The basic qualifications for a teacher and a research worker namely advanced knowledge and research experience cannot be had in Pakistan at this stage. Engineers must be sent abroad to acquire both. Efforts should be made however, to limit this period to say ten years, after which we should at least be able to do research in Pakistan in the major subjects.

Several engineers and administrators feel that opening of post-graduate classes and starting research is such an extraordinary burden that it cannot be undertaken with the existing staff and without considerable financial backing. But this is not correct. The truth of the matter is that an institution which is properly staffed for under-graduate instruction, generally, is adequate for post-graduate instruction also in a limited number of major subjects such as Structures, Fluid Mechanics, Applied Thermodynamics. Opening of post-graduate classes is a delight and not an unwelcome burden for the teachers.

At present few facilities and almost no encouragement are offered for research. But if there is a will on the part of the authorities research can be organized with very limited resources. Large funds are not needed for all the research problems which can be investigated by Pakistani engineers. Indeed it is surprising how much can be achieved with almost no expenditure.

Research is also needed in the problems of engineering education. So far practically no attention has been paid to this very important duty of our teachers. It may be hoped that as staff strengths at the colleges increase and pressure of work on the staff comes to normal research in education will be started without delay.

THE IDEALS OF WELL-ROUNDED EDUCATION

The primary function of the rounding out of the education of an engineering student should be to provide him with means of discovering a philosphy of life. A properly educated person who has reached maturity should be able to answer questions about life similar to the ones that Plato asked [10].

What should men believe about life? How should they live it? In what state of society can the good life be lived? How can we create such a state?

A philosophy of life helps man to account for his acts to himself as well as to others. It gives him a criterion for judging acts of someone else. The more coherent a philosophy of life tends to be, the more it progresses towards unification. In ideal case it would be synonymous with the German word *Weltanschauung*, which may be stated as a unified conception of the purpose of the world as a whole.

In old days, the religion of a man constituted his *Weltanschaung*. As a command from his God, he learned his duties to himself, to his family, and to society at large. He learnt what was right and wrong, good or bad. Besides the religion provided him with information about the origin of the universe and man and about the forces that keep the world going. It quenched his thirst for knowledge.

With the rise of science, the method of seeking Truth changed. Instead of the lonely mountains, deserts and monasteries where curious men used to go to meditate so that they could come back with Faith, the learned began to throng to the laboratories to find experimentally the truth about matter, the truth about life and the truth about Nature. But this era also did not last. In the words of Einstein [11]

> Fortunate Newton, happy childnood of science ; Nature to him was an open book, whose letters he could read without effort.

The rationalist-minded scientist discovered that the edifice of science that man had so zealously built was based upon the properties he himself had attributed to matter. [12] There was nothing Divine about it. Science had not proved the substitute for religion it was originally thought of. The disillusionment was tremendous.

Happily, perhaps unfortunately, we in Pakistan seem to be immune from pondering about these deeper problems of life. Superficially professing a religion, we actually are engaged on a massive scale in copying manners, morals and methods of the Western Civilization.

The sum total of the Weltanschauung of our educated man is zero.

How can this deadening curtain be lifted ? What kind of education will provide the student of today with means that he might be able to discover a philosophy of life for himself? A philosophy of life that embraces the totality of an individual's experience must be something highly abstract. A student will be able to discover it only if his powers of abstract conceptualization are well developed. To achieve this end the discipline of abstract thought that is provided by Mathematics, and the ability to comprehend abstract thought embodying life experiences that is gained by a proper study of Language, are indispensible. Thus a training in the use of abstract words and symbols is essential to the formation of a philosophy of life.

Research should also be utilized to impart a moral lesson to the engineering student. On the one hand, through the results he obtains he should acquire the confidence that he too has the ability to contribute to the advancement of knowledge. On the other hand, through the lack of certainty about the rightness of assumptions underlying his solutions he should acquire a sense of humility in comprehending the nature and limitations of man's knowledge.

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