PREPARATION OF PROFESSIONAL ENGINEERS FOR QUALITY MANAGEMENT

By

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Abstract

By virtue of their involvement in product design, manufacture, testing and servicing, engineers constitute the majority of professionals whose work has direct relation to quality. However, the traditional approach to education of professional engineers tends to impact concepts and attitudes that do not necessarily lead to the kind of perspective needed for effective quality management. The deductive learning process in analysis and design, while necessary in general engineering education, is not sufficient for quality management which calls for appreciation and comprehension of uncertainty phenomena in the physical world, proficiency in inductive reasoning, and an adequate understanding of human behaviour. An appropriate orientation in university curriculum is necessary, as mass production of engineering graduates need to man the many technical positions created in a newly industrialized society, will not be sufficient by itself to guarantee the generation of consistently high quality products and services, the mark of a truly advanced economy. Other aspects of education for quality management are discussed, and possible measures are suggested for ensuring quality consciousness and competence in the new generation of engineers.

Quality Management and Engineers

Quality management in industry is a very much human oriented operation, and human performance is in turn closely related to an individual's training and experience. By virtue of their involvement in product design, manufacture, testing, and maintenance, engineers constitute the majority of professionals whose work has direct relation to quality. It is therefore essential to examine the adequacy of the training of engineers vis-a-vis the need for quality consciousness and quality im-

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provement. Of interest here are engineers who have not been specifically trained for quality assurance but are nevertheless involved in quality management by virtue of their work duties.

Training of Engineers

In this discussion, attention is drawn primarily to the general professional courses which most practising engineers normally have to go through. Traditionally, professional engineering courses are built upon the fundamental engineering sciences, such as mechanics, thermodynamics, fluid mechanics, and strength of materials. A small number of courses, usually electives, are available to provide exposures to non-technical areas such as industrial management or subjects in the humanities. A typical graduate is one who has a fairly sound knowledge of basic engineering principles, has an adequate amount of familiarity with the theory of topics in his chosen discipline, such as electrical or mechanical engineering, but generally needs another few years of on-the-job experience to acquaint himself of the practice in his field of specialization and to build up a reasonable level of self-confidence in independent work. He would then either continue to upgrade his technical competence, or gradually assume more administrative responsibilities which in many cases lead to an eventual career in management.

Invariably, where quality is concerned, the engineer charged with responsibilities in quality assurance has the need to learn the necessary techniques and procedures from technical manuals and specifications, even though he may have taken a course in quality control in his undergraduate days. It is here that lies the root of inadequacy in approach to quality management seen in many situations. The basic reason is that veritable quality management goes far beyond procedures and specifications: much of it is based on a philosophy of which the implications are hardly in line with the concepts and methods used in problem solving in a conventional engineering education.

Conventional Approach to Problem Solving

In the first place, most drills in problem solving in an undergraduate course take the form of classroom exercises which aim at illustrating a particular theory or a particular set of techniques. To enable students and teachers to check on the mastery of theory or correctness in the choice and application of techniques, these exercises are often so contrived that, with rare exceptions, a problem is not only well defined and well structured; the amount of information given is also exactly necessary and sufficient, leading to a unique correct answer either found at the end of the textbook or announced in class at a later date. To arrive at the correct answer, it is necessary to start from first principles such as Newton's Laws of Motion, the First Law of Thermodynamics, or Kirchoff's Laws. Equations and their variations are then developed from these basic principles so that the given data can be "plugged in" for a numerical solution. Such a deductive approach, namely moving from a general theory to particular cases, is repeated many times; and since in most engineering curricula, subjects involving analysis far outnumber synthesis or design subjects, the pattern is quite firmly set in the minds of young engineers. Thus, it is taken for granted that to attack a problem, there ought to be a relevant theory and the attendant mathematical formulations; furthermore, all basic data or parameters must be available before useful results can be derived. Students are hardly presented with situations where data are on hand with their meanings unspecified and it is unknown, at first sight of the problem statement, whether the information they carry is too little or too much. Usually students would find it difficult to discover by themselves the parameters which could best describe an unknown data-generating mechanism. The inductive process of going from the particular to the general is quite foreign to most graduates, owing largely to the necessity to compartmentalize engineering knowledge into well-labelled courses that can be neatly administered within a specified span of time using the available teaching facilities and personnel.

Notion of Certainty

Consequent upon the habit of deductive reasoning is the image of a deterministic world. More often than not engineering students are told that theirs is an "exact" field of study, a statement that is true to the extent that rigorous engineering principles are expected in any analysis and design, but misleading when it comes to measuring, describing and understanding natural phenomena. Few are engineering graduates who possess the kind of mentality tuned for the perception of uncertainties inherent in many engineering processes, particularly in industrial production. The ability to recognize uncertainties in a process, to describe, to understand, and eventually to predict and control them, is most essential when it comes to quality control operations. Variations in product properties, for example, cannot be deduced from theory nor exactly specified; if they could, it would be quite possible to eliminate them altogether by some one-off manipulation of parameter settings in the production process. The "engineering of certainty" attitude stems from the fact that most curricula do not provide for teaching of probability theory and statistics in the engineering context; in most cases students develop a nodding acquaintance with these subjects only through a collection of theorems and formulas presented as part of a mathematics course: the myriad of distribution functions simply do not make much engineering sense at the first encounter, and concepts of statistical inference hardly take root because that is not the way to reason in the "hard" courses, such as electronics, mechanics, or computer programming. In any case, most statistics courses for engineers end where the subject is just about to be demonstrably useful, namely the recognition and expression of uncertainties through significance tests, regression analysis, and experimental design for data collection: the consequence is failure to gain a full appreciation of the usefulness of the subject.

The Human Element

The above common shortcomings in the perspectives of engineers in solving real-world production problems are usually compounded by a lack of understanding of human behaviour and human relations. For example, accountability in a multi-stage production process involving a multitude of personnel is again a problem to which deductive reasoning and concepts of exactness in numbers have little relevance. Usually one is faced with elements of man, machine, material, method, measurement, and management — all interwoven into complex factors that defy clear-cut theoretical analysis. The effects of personnel motivation, participation and cooperation on the overall quality performance has been well recognized, and an engineer would do far better if he has an appreciation of the role of human factors in quality management. Industrial management is a compulsory subject in many undergraduate curricula but is sometimes replaced by some humanities options. However, it is in the working environment that a young engineer is confronted with the reality of human behaviour and learns through experience the difficulties of man-machine interface and interaction. The possibility always exists that quality performance slips during the period it takes an engineer to learn and get accustomed to looking at problems from the human and cultural angles.

Proper Approach to Quality Management

To the extent that quality management calls for a "total system" concept in analyzing and synthesizing designs and procedures, an inductive approach based on observations at the operations level, incorporating human as well as technical factors is essential. The quality engineer must be able to decide, for example, the kind of information to look for, the amount of data to collect, the procedure for processing the data, the measures to use for interpreting empirical evidence, the parameters in man, machine and material to change or adjust to suit a particular quality target, the results and the range of their variations to expect, and the overall cost-effectiveness of quality management to aim at.

Towards a Reorientation in Engineering Education

The three major factors working against a proper perspective for quality management, namely the habit of deductive problem solving, the notion of certainty in measures and cause-and-effect studies, and unfamiliarity with human behaviour and management, are inherent in the format and contents of most undergraduate engineering curricula. Given the amount of fundamental principles and techniques to be taught in the limited span of time available, it seems difficult to incorporate additional training in an engineering curriculum for rectification of the situation. Some alleviation, however, may be effected through several measures. For example, more "discovery" type of laboratory experiments should be instituted; students should not be made to take measurements with a view to "verifying" an expected phenomenon dictated by a natural law, but rather be guided through data collection procedures in empirical model building exercises. The study uncertainties in natural phenomena and methods of their measure and control should next be introduced, leading to facility in the methods of statistical inference: to this end, probability theory and statistics should be taught by engineers, not mathematicians. The idea that engineering work is mainly predictive and precise should be carefully qualified at the outset. At a later stage, studies in industrial management and behavioural sciences should be so conducted that quality control could subsequently be viewed not as an entirely statistical problem but one that is very much human oriented: for example, the role of the foreman in a quality improvement programme, especially when a unionized workforce is involved, bears some thorough examination. In addition, principles of engineering economic analysis, coupled with maintenance and replacement theory, should be presented so that the nature of quality-cost trade offs is well understood. Thus, the graduate should ideally emerge from an engineering course ready to serve as the interface between purely technical and management personnel, unbaffled by any phenomena which do not lend themselves to analysis by first principles of engineering science, or any operative procedures that have been developed to accommodate human needs and priorities rather than technical consideration.

It is also essential to ensure that formal training opportunities exist for working engineers to acquire the skills of data collection, processing, interpretation, and system analysis. These will lead to rational decision analysis and operations management that will prevent conflicting goals or actions within an organization. Unfortunately, continuing education opportunities in these areas are still not generally available, but this is the responsibility of professional organization and extension or extramural departments of higher institutions of learning.

Given that engineering knowledge needs to be prepacked according to neat labelling systems so that it can be passed on in such a way that its potential half-life for an engineering graduate is made as long as possible, it is still possible to provide an education capable of preparing future professional engineers for imaginative and intelligent quality management. The key to achieving this is development of a capability to view a problem with a mentality that is active instead of reactive, diagnostic instead of prescriptive, practice-oriented rather than knowledge-oriented, and human-dependent rather than purely technique-dependent. The stress should be on what engineering problems really are, now how to solve them in the ideal form, and the recognition that there is no authority in the real world that holds the "right" answer against which an engineer's solution is judged In this respect, industry

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could help by generating more feedback to institutions of learning as to what kind of problems are of current and potential interest, and by providing more practical training opportunities to undergraduates. At the same time, industry could be more sympathetic to young graduates suddenly faced with a problem solving environment totally different from the world of lecture rooms, libraries and laboratories.

Conclusions

In the foregoing sections, a broad overview has been presented without getting into the specifics, such as quality control practices and aspects of quality control circles, which are available in the literature. The possible inadequacies in conventional undergraduate engineering education have been identified with reference to quality management, but it is clear that these factors tend to affect other "real world" engineering efforts as well. An appropriate orientation in the undergraduate curriculum is necessary, as large scale production of engineers trained up in the conventional approach, while nominally meeting the need to man the numerous technical positions created in a newly industrialized society, will not be sufficient to guarantee the generation of consistently high quality products and services, the mark of a truly advanced economy. This being the case, it remains for the educationists and industrialists to establish constant interactions so as to generate useful and timely inputs for possible upgrading and updating of the basic engineering curricula.