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FROM THE EDITOR

This issue of our newsletter features articles that address two significant - and related - topics as they apply to the system of engineering education: Total Quality Management (TQM) and Design. The concept of "TQM" is introduced to academia by John A. White in his article, "TQM: It's Time, Academia." Dr. White's article challenges the prevailing standards of the quality of our system of engineering education by examining key factors such as the attrition rate of engineering students, the time required to receive an engineering degree and the cost of higher education.

"Design in Engineering Education," by Jerrier A. Haddad addresses a sub-element of TQM, the teaching of Design and its practice in industry. Along with his discussion of the teaching of Design, Mr. Haddad offers his views regarding the Accreditation Criteria which should be applied in order to convey a total design experience to the graduating student.

We feel that both articles provide unique and thought-provoking views and recommendations regarding many of the current issues which impact the quality of engineering education.

Robert L. Sullivan

TQM: IT'S TIME, ACADEMIA!

John A. White

Dr. White is presently acting Deputy Director of the National Science Foundation. This paper is based on a presentation given July 18, 1990 at the First National Symposium on the Role of Academia in U.S. National Competitiveness and Total Quality Management, hosted by West Virginia University. Dr. White was invited to provide a perspective from academia on the impact of TQM on academic institutions; although his remarks are directed toward U.S. Colleges and Universities, many apply to all educational institutions worldwide. The remarks made at the conference, as well as those in this paper, represent Dr. White's personal views and do not necessarily represent official policy of the U.S. National Science Foundation, or the IEEE. Dr. White has granted permission to reproduce this article in the EDUCATIONews.

Introduction

The quality of America's educational system is receiving widespread attention, with much of the focus directed toward precollege programs. The President's educational summit and consequent commitment for America's high school graduates to be "first" in math and science by the end of the century (3,452 days from now!) are representative of the emphasis being given to improving the quality of education. While some may believe that essentially all of the Nation's resources should be directed toward the precollege educational "crisis," I favor a portfolio approach with a greater emphasis on the undergraduate programs in engineering, math and science.

The Nation's colleges and universities are facing a three-fold challenge that must be addressed -- soon! The decline in the size of the college-age population between now and the end of the millennium will reduce significantly the production of engineers and scientists during a time in which science and technology are emerging as the "formidable competitive weapons" in international competitiveness. The attractiveness of engineering and science is declining among today's students; engineering and science are not necessarily the majors of choice among the Nation's "best and brightest" young people. The demographic shifts that are underway will yield a population that has not historically opted for engineering and science; specifically, engineering, and science continue to be less appealing to women, underrepresented minorities, and persons with disabilities than to the remaining segment of the population -- which is diminishing in relative size!

Given the challenge facing America's colleges of engineering and science, it is especially important for today's educators to increase the appeal of engineering and science to all segments of society; at the same time, degrees in engineering and science must be competitive with the best in the world. In this paper, I focus on one of the systemic changes that must occur if America's engineers and scientists are to maintain and improve their relative position in international competition -- total quality management (TQM).

The paper is organized into two major sections: teaching TQM and practicing TQM, with the latter receiving the greatest attention. In treating the practice of TQM, I address the teaching, research, and service roles of the university.

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Teaching TQM

In addressing the pedagogical aspects of TQM at academic institutions, three fundamental questions must be answered. Who should be taught TQM? What should be taught? Who should do the teaching? Although I will forego consideration of the content of course material, I do feel it is useful to consider the human aspects of the question, the "who" questions -- who should be taught and who should teach.

First, all faculty and staff should be taught (at varying degrees) the concept and fundamentals of total quality management. Next, all students should be exposed to the subject, for all will ultimately be called upon to practice it regardless of what they undertake for their life's work.

As to who should teach courses in TQM, I believe each departmental faculty should decide the issue for their students. For, it will be the case that some majors will require in-depth exposure to TQM, while others will require only a brief exposure. Having said this, I must hasten to add that I believe all engineering students should receive an in-depth exposure to TQM. A failed telescope in space, a catastrophic shuttle mission, oil spills in rivers and oceans, a failure at a nuclear power plant, a collapse of a bridge or building, a rupture of a dam or chemical vessel, an explosion of a munitions plant, and a wrist watch that no longer works -- all have in common the fact that something went wrong, something failed! Engineers must design safe and sound products and systems; they must practice total quality management regardless of their specialty.

Drucker[1] has emphasized the difference in efficiency and effectiveness by noting that efficiency means doing things right and effectiveness means doing the right things. In teaching TQM, it is critically important that the right things be taught right. The subject is too important to be taught by someone who is incapable of conveying both the spirit and the content of TQM.

Having considered the teaching of TQM, it is obvious that academia also must practice what it teaches! Specifically, it should practice TQM in the teaching, research, and service missions of the university. The next section explores the opportunities for practicing TQM in academia and treats a number of the challenges to be faced.

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EDUCATIONAL ACTIVITIES DEPARTMENT
The Institute of Electrical and Electronics Engineers, Inc.
445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, U.S.A.

EDITOR: Robert Sullivan, Florida Institute of Technology
MANAGING EDITOR: Rae Toscano (908) 562-5482
CONTRIBUTING STAFF: Angela Bergman, Lisa Marcy, Rose Jackson
STAFF DIRECTOR: Rudolf Stampfl
V.P. ED. ACTIVITIES: Richard Nichols, CH2M Hill, Corvallis, OR

FAX (908) 981-1686

Practicing TQM

Practicing TQM in the Teaching Mission of the University

Before treating the practice of TQM in academia, it is useful to consider the following questions:

- How long would a firm be in business if it rejected parts, materials, and subassemblies at an overall rate of 35% and rejected a critical component at a rate of 65%?
- How long would a firm be in business if it consistently failed to meet its advertised delivery dates by 25%?
- How long would a firm be in business if its products failed to satisfy over half of its customers?
- How long would a firm be in business if it paid little attention to its cost of production, but instead raised prices at a rate considerably above the cost of living while competitors were entering the market with lower prices?

What do these questions, obviously based on an industrial model, have to do with TQM in academia? Consider the first question, which uses rejection rates as an analog for student attrition in the university. The attrition rate of students who enroll in engineering, in my view, is unacceptable; it hearkens to an age when it was common to hear freshmen "motivated" using a boot camp style by admonishing them to "look to the left, look to the right, they won't be here in four years!" While I never used or favored such an approach, it persisted in the face of demand for engineering degrees exceeding perceived supply-side requirements. Today, such an approach borders on the suicidal for the Nation.

Overall, roughly half of those who enroll in the university as freshmen with a stated interest in majoring in either natural science or engineering (NS&E) will ultimately receive an NS&E degree. Since many universities do not "count" students as engineering students until some time later in the process, roughly 65 percent of those who actually enroll in engineering receive an engineering degree. However, among underrepresented minorities, the comparable figure is 35 percent. While women students have a lower attrition rate than underrepresented minorities, it is greater than that for men. Further, a declining reason for the attrition of women is academic difficulty.

The time required to receive an engineering degree is the subject of the second question. Very few students complete the engineering degree in four academic years. Those who finish in four calendar years generally attend summer school. Instead of engineering being a 4-year program, it is more nearly a 5-year program.

As the third question implies, less than half of those who declare an initial interest in engineering are ultimately satisfied with the experience, including many who "tough it out" and graduate!

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[1] Peter F. Drucker, The Effective Executive, Harper & Row, Publishers, New York, 1967.

The last question focuses on the cost of higher education, which has risen far faster than the cost of living. While this is true for all institutions, it is especially true for a select number of private, liberal arts schools; they have learned that the business of higher education can be a very good business indeed, since the higher the tuition the greater is their enrollment demand! However, considering the years of schooling required and the "psychological cost" of majoring in engineering, it probably has grown at an even faster rate. As a result, students are seriously questioning the "total cost" of majoring in engineering.

Having considered the relationship between industry producing products and academia producing graduates, it is worthwhile to consider the questions: who is academia's customer and what is academia's product? Some argue that the consumers of academia's graduates are its customers; others argue that the students are the custumers, since they can choose to "buy" or "reject" the academic programs offered by academia. Which argument is correct?

In many ways, academia functions as an agent for the student; the university is a broker not unlike a real estate broker. Who is the real estate agent's customer, the buyer or the seller of the house? Contractually, the agent represents the seller, since any commission is paid by the seller; however, the seller pays the agent from receipts provided by the buyer. Thus, for a real estate agent to be successful in the long run, both the buyer and the seller of the house must be satisfied with the experience. I believe both its students and the consumers of its graduates are academia's customers. Of the two, the most important is the student. For, ultimately, the success of the graduate will determine the level of demand for future graduates. Finally, academia's product is not its graduates, but the education it provided.

If the student is the most important customer of the university, whose failure is it if a student fails a course? In applying TQM in business, the customer is "king"; the customer is always right! In business, every attempt is made to satisfy the customer. Interestingly, in academia the emphasis is on the customer (student) satisfying the producer (academia).

Although I have assumed the reader is familiar with total quality management, I do want to clarify the definition of quality I use in the paper. Case[2] defined quality as "what the customer says it is." This brings us to the crux of the matter! For TQM to be applied in academia in a similar fashion to its application in industry, academia must turn its world upside down; many of the "givens", many of the paradigms of the past must be discarded.

As I noted in another setting[3], "Today, there is too much dependence on selection processes and not enough dependence on development processes. We have refined to an ultimate degree the selection process. Dr. James Duderstadt, President of the University of Michigan and a member of the National Science Board, pointed out this aspect of higher education. He noted that universities have depended on selection processes in the recruitment of students and faculty. Unfortunately, little or no attention is given to developing human potential. The true 'value added' by the educational system must be questioned.

"We ensure that only the best students are admitted as undergraduates, only the very best of those are allowed to go to graduate school, only the very best of those will graduate, only the very best of those will be hired as assistant professors, and only the very best of those will become tenured. That process might have worked with the input stream of the past, but it is not likely to be effective in dealing with future input streams.

"We must pay more attention to those who might be at the margin--those who, with a little development effort, can be transformed into superstars. We must find a way to effect the transformation. I'm reminded of the young fellow who was hiking on a mountain trail he had never hiked before. At one point on the trail he noticed a sign that read, 'Pick up some pebbles from the pile at the base of this sign. Put them in your pocket. At the end of the day, you will be both glad and sad.' He looked at the pile of rocks, chose two of the smallest pebbles, and put them in his pocket. After hiking all day, as he was about to go to sleep he remembered the pebbles. When he removed them from his pocket, he found that they had turned into gold. He was very glad he had picked them up; he was very sad that he hadn't picked up bigger and more pebbles.

"We must recruit more of the 'marginal' students; at the end of four years we'll be both glad and sad. We'll be glad that we paid attention to the ones we did and we'll be sad that we didn't pay attention to more of them. We must develop a mentoring capability within engineering, we must pay much more attention to the development of the human resources made available to us; we must acknowledge their scarcity; and we must replace a 'weeding out' philosophy with a 'bringing in' or 'cultivating' philosophy. We must place greater emphasis on nurturing and developing. This will require a major change in the culture of engineering education. Pogo was right in identifying the enemy."

Unfortunately, it appears that academia is making the same mistake industry made for decades, trying to "inspect quality into its products." Under TQM, firms design quality into the products; less emphasis is given to inspection and more emphasis is given to "front-end" planning and design. How does this apply to academia? Entrance exams; tests, quizzes and final exams in courses; and qualifying exams, comprehensive exams, and dissertation defenses are forms of inspection -- they are attempts to "inspect quality into the product."

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[2] Kenneth E. Case, "Quality Control and Assurance," Chapter 3.6, Production Handbook, John A. White (editor), John Wiley & Sons, Inc., New York, NY, 1987, p. 396.

[3] Remarks made during a public address at Rennsselaer Polytechnic Institute, titled "As a Venture Capitalist, Would You Invest in America's Engineerng Education Enterprise?" The address was given on May 18, 1990 and recorded in a paper prepared on June 11, 1990. Copies are available upon request from the author.

I am not advocating an elimination of all "inspections", but I am advocating an attack on "defects" where and when they occur. In industry it is far better to cure the cause of the defect than to continue to reject defective parts! Likewise, in academia more attention needs to be given to identifying the source of the "failure." In my judgement, when a student fails a course, it is because of a failure in the teaching/learning process; both the student and the professor are jointly culpable. However, under our current system, only the student pays the penalty for the lack of successful education on the part of the professor.

Engineering is losing market share to law, medicine, accounting, and business in the competition for women students. We must redesign our products to appeal to this and the next generation of students; we must improve the quality of our products. TQM provides the mechanism for accomplishing the needed transformation. To ensure that changes are made consistent with the demands or our "customers", we need to spend more time listening to our students, to the employers of our graduates, and to our faculty. We must understand much better the nature of the "business" we are in.

Peter F. Drucker[4] says that every manager must answer the question, "What business are we in?" Next, he asks that managers answer the question, "What business should we be in?" Some would argue that academia's business is the knowledge business; however, I believe it is the business of producing knowledgeable people. Higher education is in the people business. As such, academia must maintain its focus on its people: its students and its faculty and staff.

How important is the teaching mission of research universities to their faculty? Students know how important they are to the faculty. They are reminded daily of their importance. For that reason, it is not surprising that "last minute" attempts to recruit undergraduate students to attend graduate school are so unsuccessful; what is surprising is the few faculty who recognize the connection between their own attitudes toward teaching undergraduate students and their recruiting difficulty. You cannot suddenly recruit students for graduate school in the latter part of their senior year and expect them to discount all of the messages you sent during the previous three and one-half years. By the end of the sophomore year, it is fairly obvious which students have high-potential for graduate school. Yet, we don't pay much attention to them until they're seniors.

What business is academia in? I believe it is in the human resources development business and the business of producing knowledgeable people. However, it is not necessarily the case that the institution which produces the most knowledgeable people does the best job in educating its students. Why? Because the "value added" by some institutions is questionable; they produce the "best people" because they attract the best people. In some cases, it appears that academia is no more than a convenient "holding ground" for students to mature. Hence, the greatest competition is not in the classroom, but in the admissions process. Since there is little confidence in the institution's ability to discriminate once a student is enrolled, applicants are carefully scrutinized and "only the best" are admitted.

In statistical experiments, as well as in establishing statistical quality control limits on a process, we guard against two kinds of error: rejecting an hypothesis that should be accepted (Type I error) and accepting an hypothesis that should be rejected (Type II error). Similarly, educators are concerned with two kinds of errors: not passing a student who should pass a course (Type I) and passing a student who should not have passed a course (Type II). Unfortunately, faculty appear to be more concerned with reducing the Type II error than with reducing the Type I error.

If TQM is to be applied to the teaching mission, we will have to develop a mechanism for coping with the inherent process variation that exists. Sources of the variation include: students, their previous educational backgrounds, attitudes, abilities, and goals; faculty, their preparation for teaching, attitudes, abilities, and goals; and the infrastructure, including laboratory and computing equipment, involvement with industry, library resources, furnishings of classroom and study rooms, and housing.

Due to the diversity of students, faculty, and infrastructure combinations that exist, it does not appear reasonable to expect "cookie cutter" approaches to be effective in carrying out the teaching mission of the university. To the extent possible, tailored curricula should be used to meet students' educational needs. This does not necessarily mean smaller class sizes, though that would help; neither will it be necessary to increase substantially the number of courses offered. What it does mean, however, is allowing greater flexibility in terms of the courses taken and the speed at which a student moves through the curriculum; it also means adopting computerized instruction to a greater extent.

United Airlines flight test facility in Denver is an example of the kind of approach to education I believe should be provided for more students in the university; their philosophy, basically, is that every student should graduate. They accomplish their objective by paying careful attention to a student's progress continuously, by allowing the student to establish the educational pace, and by providing considerable computerized instruction and feedback to the instructors.

It is generally the case that universities are attempting to perform "high tech education" by using "low tech processes." Faculty tend to use teaching techniques that have not changed in decades. Perhaps flexible teaching systems (FTS) and computer integrated teaching (CIT)[5] are needed.

For a number of reasons, universities have focused on the high cost, low volume end of the market (i.e., the doctoral market) and are giving less attention to the higher volume market that sustained them for years (i.e., the undergraduate market). As a result, the process could be characterized as producing Washington Monuments when Capitol Buildings are in demand. The Washington Monument is tall and narrow and symbolizes the belief that undergraduate students will only have value if they become doctoral students. Many faculty appear to believe that every student is in the university in order to one day be a faculty member. For engineering, a new model is needed; we should be designing the Nation's Capitol Building, not the Washington Monument. "We need to recognize that the vast number of undergraduate students will enter professional practice. They will help American industry be competitive; relatively few of them should go on for a master's program and even fewer should go on for doctoral studies.

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"We should not focus our educational system on the production of the very few who will be Ph.D.'s. Rather, we should give greater recognition to the base of the Capitol, i.e., those who do not go beyond the bachelor's degree. We should make the bachelor's experience a quality experience, one that will benefit the student and industry. Next, we should focus on the few who go on to the dome of the Capitol by becoming graduate students. Finally, we should consider the pinnacle of the Capitol, those who might get their doctorate. We must give greater focus to the basic mission of undergraduate engineering education; we must pay more attention to the base of the Capitol."[6]

Practicing TQM in the Research Mission of the University

As we turn to a consideration of practicing TQM in research, I must admit that I have been impressed with the apparent ability of NSF's program directors (as well as the research community, itself) to judge the quality of research *before it is performed* and on the basis of surrogate (and in some cases, scant) evidence. When a reviewer or a program director is asked to justify their recommendations with respect to a research proposal, the response is always the same, "The ones with the highest quality are funded." I'm not as confident that my quality judgements are as error-free as they.

In fact, because of the surety of the claims regarding quality, I often wonder if we aren't erring on the side of conservatism in our judgements, taking the safe path instead of the more risky path. Is our quality measurement system filtering the off-beat, the radical, the potentially highly innovative idea?

Ideas are not like screws and bolts. We cannot employ calipers in measuring the critical dimensions of an idea; hence, we cannot make perfect judgements as to the quality of an idea. At NSF, our calipers are the peer review process. As such, we recognize that the judgement of quality is a qualitative judgement. While I do not claim that it is perfect, I do believe no better system is in use.

Yet, improvements can be made. We periodically revisit the peer review process in search of ways to improve it. In fact, we are currently engaged in such an exercise.

Not only can improvements be made in NSF's peer review process, but also the national research system can be improved. For example, greater accountability and scientific openness are needed, especially in the case of federally funded research. The recent difficulties at NIH have raised our consciousness regarding scientific integrity.

On the one hand there is the need for greater accountability; on the other hand there is the impact of bureaucratic accretion on the performance of academic research. To be sure, a balance is needed. Since taxpayer dollars are being used, we are charged with investing them wisely, to be good stewards of the Nation's scarce resources. Resisting added scrutiny are the universities who cannot afford to participate in the process, which is escalating the cost of research.

On a different note, it appears that many in the academic research community believe it is their inherent right to receive research support from the Federal Government -- *no strings attached!* Many in academia (including faculty members and university administrators) appear to view NSF as an academic entitlement program. Such is far from the case! NSF's mission is inextricably tied to the Nation's condition; the economic health of the Nation will affect NSF's ability to support research and, I believe, that support should be related to the impact of NSF's research on economic competitiveness. As such, I believe more attention should be given to meeting the needs of U.S. industry in forming NSF's research agenda.

In engineering research, new paradigms are needed. Specifically, more emphasis should be given to "making a difference" with one's research; less emphasis should be given to publishing yet another paper in a prestigious archival journal that relatively few will read, and its only impact will be to serve as the launching point for another paper by the same author! Less emphasis should be given to pseudo-scientific research and more should be given to industrially relevant research.

In academic research, I believe the educational experience of the student involved in the research is more important than the research results. As such, it is especially important for attention to be paid to the quality of the student's research experience. For, I believe that the quality of that experience is far more important than the quality of the research output. Academic research has a two-fold purpose, educate students and produce results; I believe the former is far more important than the latter. Yet, the recognition/reward system in the university places greater weight on the latter than the former.

In academic research, more emphasis must be given to what is in the best interest of the student, what is in the best interest of the Nation, and what is in the best interest of the university. Less emphasis should be given on what is in the best interest of the professor.

Why do I make such a claim? Most faculty appear to make decisions as to what to teach, what to pursue in research, and which graduate students to support as teaching and research assistants on the basis of what is in their interests, not the students'. As a result, there are few incentives for a professor

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[4] In Management: Tasks, Responsibilities, Practices, Harper & Row, Publishers, Inc., 1974.

[5] FTS and CIT are the teaching counterparts to FMS and CIM technology used in manufacturing.

[6] John A. White, "As a Venture Capitalist, Would You Invest in America's Engineering Education Enterprise?"

to accelerate a graduate student's academic program; there is little incentive to recruit American undergraduate students for graduate school as long as there is a ready supply of hard working, uncomplaining, highly capable foreign students; and there is minimal incentive to perform service functions for the university. Unfortunately, the "what's in it for me?" attitude is evident to all, especially the students.

Practicing TQM in the Service Mission of the University

From the foregoing, it is evident that I believe considerable progress is needed in improving the quality of the service mission of the university. Not only should TQM be practiced in the university's service to society, to the state and local region, and to alumni and supporters of the university, but also it should practice TQM in its service to its students and employees.

Sadly, the quality of the service function is abysmal at many universities. Unfortunately, too few service functions understand they are in the business of providing quality service; too few who staff the functions are service-minded. From my perspective, the quality of the service it provides to its students and employees should be the highest priority of a university's administration. In the case of students, every effort should be made to make the student feel important, rather than a number. The registrar's office, the student aid office, the office of student fees, the housing office, the athletic office, buildings and grounds, security, food service . . . these are just some of the organizations in a university that were established ostensibly to assist students and make their stay at the university tolerable if not pleasant. A similar list could be constructed for faculty and staff.

On numerous occasions, I have heard it said by faculty, administrators, and those employed to perform a service for students, "The university would be a great place to work if it weren't for the students!" It was obvious that such individuals did not recognize their own dependence on the presence of students; furthermore, TQM was not a part of their job performance. Unfortunately, too few in the university appear to truly care about students. For this reason, it is essential that TQM be introduced to academic institutions.

Summary

In summary, TQM will not be adopted within the university without strong support from the upper administration. Furthermore, that support should be tangible and highly visible. An essential part of the administration's support package is a recognition/reward system that promotes TQM performance. Because of the inherent competitiveness among academic institutions, a national award like the Malcom Baldrige Award could stimulate widespread adoption of TQM. However, because of the copy cat tendency of universities, its success depends critically on having "the right universities" participate. If the institutions that others "want to be like" (i.e., the Top Ten in the *U.S. News & World Report* rankings) are among the participants, then I am more confident of the success of the award process.

I have no misgivings concerning the time and commitment required to implement TQM in an academic institution. To be successful, systemic change must occur; however, it has long been the case that managing change is a key to success in today's world. Rosabeth Moss Kanter, in her book, *The Change Masters,*[7] emphasizes the importance of integrated thinking within organizations that are facing dramatic change.

In most institutions, the level of change required for TQM to be successful is total cultural change. To remain competitive, many firms have undergone cultural changes; there has been a major restructuring of "corporate America"; similarly, a restructuring of "academic America" will be required to accommodate TQM.

In their book, *Corporate Cultures,* Terrence E. Deal and Allan A. Kennedy stated, "Changing the culture of an organization is a difficult, time-consuming, often gut-wrenching process. This is as true in public corporations as it is in the private domain. In fact, effecting such changes in a public institution is, if anything, more difficult because of the number of legitimate constituencies -- the public, legislators, unions, employees, special-interest groups -- that can raise barriers to change. But change can be accomplished if a sufficient level of commitment is applied to the process for a long enough time."[8]

Changing an academic culture is surely more difficult than changing the culture of a public corporation. Further, to do so will take a strong commitment from the university administration, a commitment of time and resources. With respect to the time and expense of a cultural change, Deal and Kennedy also noted, "Once it becomes obvious that change is necessary, there are two other tough facts to face: change is time-consuming and very expensive."[9]

In conclusion, TQM would appear to be appropriate for the academic institution that is "in search of excellence"[10], "managing for excellence"[11], "creating excellence"[12], or just has "a passion for excellence."[13] If anything, academia needs TQM more than industry. Will it be adopted? The answer to that question will depend on what comes from this conference.

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[7] Published by Simon & Schuster, New York, NY, 1983.

[8] Published by Addison-Wesley Publishing Company, Reading, MA, 1982, pp. 169-70.

[9] op. cit., p. 161.

[10] Thomas J. Peters and Robert H. Waterman, Jr., In Search of Excellence, Harper & Row, Publishers, Inc., New York, NY, 1982.

[11] David L. Bradford and Allan R. Cohen, Managing for Excellence, John Wiley & Sons, Inc., New York, NY, 1984.

[12] Craig R. Hickman and Michael A. Silva, Creating Excellence, New American Library, Inc., New York, NY, 1984.

[13] Thomas J. Peters and Nancy Austin, A Passion for Excellence, Random House, New York, NY, 1985.

DESIGN IN ENGINEERING EDUCATION

J. A. Haddad

The following article is from a paper, which was presented by J. A. Haddad at the 1990 Accreditation Board for Engineering Technology Annual Meeting, on October 18, 1990 in Denver, Colorado. Mr. Haddad is a Director of ABET, an IEEE Representative to ABET, and the 1991 Secretary of ABET. His views are reflected in the new ABET Criteria on Design accepted for first reading.

Some assert that DESIGN is what separates engineering from Science. Others assert that DESIGN is fundamental to the engineering function. I believe that both assertions are partly - but not wholly - true. Let me explain.

In this day and, age many (but not all) engineers do a lot of science, and many (but not all) scientists do a lot of engineering. The engineering that scientists do is involved in conceiving, designing and building experimental equipment including optical and radio telescopes, particle accelerators, spectrometers, and ion exchangers - to name a few. Sometimes, these find a ready market. The science that engineers may do involves learning enough about a newly-observed effect to be able to conceive, design, build and sell some product or service.

I don't think it necessary to elaborate on the engineering that scientists do. Many are so good at it that, by choice, they become engineers and even business leaders. For that matter, about thirty percent of the employed engineers in this country are people who have mathematics or science degrees and through experience and self-study have become engineers. Industry knows that they are engineers; the Bureau of Labor Statistics knows that they are engineers; and, most importantly, they and their colleagues know that they are engineers. For some (but not all) people in the engineering profession to say that these people are NOT engineers is an exercise in frustration. I see nothing on the horizon that foretells the end of this phenomenon.

On the other hand, the science community is pretty snooty when it comes to admitting that many engineers do good science in the process of doing good engineering. We engineers have, since the beginning of time, made useful products without full scientific understanding of the materials, the processes, or the long-term effects of our products. Understandably, on many occasions we have come a cropper. Throwing the effluent from a few power plants into the air is no big deal. Doing it from hundreds or thousands of power plants is something else again.

As we made semi-conductor memories with smaller and smaller elements, we noticed that random errors were becoming more and more of a problem. We had to do a little science to find out that cosmic radiation was the cause and then design the memories so that error correction took care of the statistical effect.

As we made the interconnecting wires on the silicon substrates finer and finer, we noticed that these wires started breaking after a while. We had to do a little science to find out that we had microamperes of current causing current densities of hundreds of thousands of amperes per square centimeter, and that was causing metallic ion migration. Metallic ion migration? That was a new one. Now scientists study ion migration as a matter of course.

Now, to address the notion that DESIGN is fundamental to the engineering function. It is, but only if one restricts the definition of the engineering function to a remarkably narrow range of activity. The fact is that the engineering function does encompass DESIGN, but is not restricted to DESIGN. There are many engineering jobs or functions that do not necessarily involve the DESIGN function. Applied research, sales engineering, middle and high-level engineering management, field engineering, maintenance engineering, engineering pathology, teaching at any level, academic administration, maritime operation, aerospace operation, manufacturing inspection, manufacturing management, technical purchasing and on and on.

Any of us would want to put engineers in these jobs, engineers capable of doing design even if the assignment does not call for design. Conversely, we would be uncomfortable in the extreme if a non-engineer were in any of them. In most cases, the individuals in these jobs do not do DESIGN, at least they do not as a regular and principal part of their responsibilities.

Broadly speaking, in most engineering education programs there are two categories of things which are not universally treated:

1) Company Specific Education. Clearly, this is something that is quite necessary for a successful career, and on the face of it, must wait for the company to handle in its own way. No academic institution has the know-how to do this in the specific terms that are necessary. Each company has its own culture, and each new employee - experienced or not - must learn the ropes when newly employed. The culture will even extend to subjects like design methodology as well as things like personnel practices.

2) Elements of Engineering Practice. What are the elements of engineering practice? They are many. Also, they are not required of each engineer in a particular job in the same intensity as required by another engineer in a different job. Thus, these elements of practice should not be covered in academic detail in the nominal four-year program. Rather, they should be "covered in passing" in the regular curriculum. Some of these practice elements are: design, cost accounting, marketing, manufacturing,

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J. A. Haddad, *continued*

service, ethics, patents and copyrights, safety, pollution, industrial design and quality.

Clearly, a practicing engineer need not be expert at all these topics. However, it is necessary to have been exposed to these topics enough to be able to do a proper job of design in the context of the assignment. Having familiarity with these topics is essential to being able to do a good and a complete engineering job. Knowing enough about these topics to be self-sufficient in them would be overdoing it. Further, every industry and every company within that industry has different emphasis on each of them and different ways of achieving the required results.

This is nowhere more evident than with regard to the element DESIGN. Each company has its own design philosophy. In large companies, each department may have different procedures - if not different methods - of design.

All this is not to say that DESIGN is not extremely important as an element in engineering education. It is. But it should not become a preoccupation and take precedence out of context with the other elements that are necessary to making the design successful. It is of vital importance that the student get a "feel" for the different approaches to DESIGN. A college cannot take the place of the company and drill the student in depth with regard to a specific DESIGN approach.

Engineering work stations are getting to be ubiquitous in industry. There must be more than a dozen different work station manufacturers, each with different products on the market. The student needs to know what a work station is and what its capabilities are. The student also needs to know what its limitations are, and how and when to do engineering with one of them. The college cannot teach all about every work station on the market. There isn't enough time. Also, the student may go with a company that uses a different kind of work station - or it may not use work stations at all.

To allow a student to get an engineering degree without some exposure to work station operation would be a sin. To require undue expertise at one would be worse.

The ABET DESIGN requirement is a very necessary one. However, the other elements of engineering practice need to be put into perspective with it. Further, and most important, courses that teach the student how to design (rather than requiring the student to do the design) are not specified as to whether or not they contribute to the required 16 hours of DESIGN. We must clarify that issue both for the sake of the faculty and the visitors.

Another point is that we are confusing the act of DESIGN with the act of entrepreneurship. Both are important, but we should distinguish between them. Deciding on or conceiving a design "problem" is an act of entrepreneurship. Performing the DESIGN is DESIGN. If we require more than the design process in the design requirement, then we should call it by a different name.

It is conventional wisdom to state that design is interdisciplinary in nature. For that reason, we should consider recommending that the design problem involve more than one discipline, whether or not there is a design team consisting of more than one student.

Some people seem to feel that the senior design course should be comprehensive and cover - as much as possible - elements of the entire curriculum. I don't believe that we should confuse a DESIGN course with a comprehensive examination of the student's retention of the engineering curriculum. The senior design course should seek to expose the student to the DESIGN process as well as SOME OF THE OTHER ELEMENTS OF ENGINEERING PRACTICE. This is a big enough order if done properly.

At present, and without any real guide for deciding, the faculty decides the DESIGN content of courses that were fundamentally prepared as engineering science courses. Nowhere is it required that this judgement be articulated and defended. What is worse, nowhere is the faculty asked to relate to each other all the various exposures to design in these engineering science courses.

It is impossible for the visitor to know whether or not the students are being prepared in a complete and well-rounded manner to be able to attack successfully the senior comprehensive design experience. The visitor is put in the position of being the judge and jury in determining whether or not an appropriate judgement has been made, and this without any documentation or rationale. I believe that some guidance should be given for making this judgement, keeping in mind the point previously made regarding the teaching of how to design.

There is a question as to whether or not building a model and testing it should be recommended. I only point out that some schools try to include it and some don't. Including it demands a great deal more effort and gives a great deal more experience. At least we should suggest that the hourly credit granted properly reflect the difference. Doing a first design is a good experience. Adding to that experience of constructing and testing, and possibly doing a redesign, adds considerably to the educational experience (and effort). We should distinguish between the two. In short, I believe there should be a major requirement for a comprehensive senior design experience. Also, the curriculum leading to it should be designed so as to prepare the student to succeed at this experience; and the faculty should be prepared to articulate how this preparation is conceived and practiced. Further, we need more texts on the methodologies of design, and more research leading to the writing of these texts.

Lastly, the students should be exposed to the other elements of engineering practice as a part of this integrative design experience.

ENGINEERING EDUCATION IN THE UNITED STATES

A Joint Entity Position Statement of the IEEE Educational Activities Board and the IEEE United States Activities Board

A MESSAGE FROM THE V.P.

Nothing has a greater impact on the future vitality of a profession than the health of the educational system that prepares its future practitioners. Recognizing this, the IEEE devotes considerable effort and attention to engineering education throughout the world. During the past several months, an ad hoc committee of the Educational Activities Board (Joseph Bordogna, Edward Ernst, and Jerrier Haddad) developed a document on "Engineering Education in the United States." With input from members of the United States Activities Board, the EAB committee on Issues in Engineering Education cast this document in the form of an entity position statement which has been approved and is now being issued jointly by the EAB and the USAB. This statement lists a number of areas considered by the IEEE to be crucial for the continued development of engineering education in the U.S. Officers and members of the Institute are urged to promulgate the text of the statement to Electrical Engineering departments and schools of engineering and to encourage the adoption of its recommendations.

Richard S. Nichols, P.E.

The United States' system for the education and training of engineers, technologists, and technicians faces new challenges, and IEEE must play a part in finding new approaches for meeting theses challenges. A task force of the American Society for Engineering Education studied our system in considerable detail and in the report, "A National Action Agenda for Engineering Education," made recommendations for strengthening and improving it. The Educational Activities Board and the United States Activities Board of the IEEE commend this report and support its recommendations.

In particular, the Boards urge that significant attention be focused on the following areas:

PRACTICE AND DESIGN:

1. A practice orientation, including the principles of engineering design leading to the manufacturing and fabrication process, should be given a more central role in undergraduate programs.

CAPABILITY FOR CAREER-LONG EDUCATION:

2. The four-year undergraduate engineering program should be designed by engineering faculties to provide the knowledge base and capability for career-long learning.

PRACTICE ORIENTED GRADUATE PROGRAMS:

3. Master's level degree programs focused on engineering practice should be developed by engineering faculties in a variety of technological specialties. Baccalaureate students who wish to pursue careers in engineering practice should be encouraged to complete these programs on a full-time basis as the appropriate route to a working depth of knowledge and skill. These programs should have a status equal to that of Master's level programs focused on research.

LABORATORY STUDIES:

4. Engineering faculty need to rethink the objectives of laboratory instruction and find innovative ways for satisfying those objectives. At minimum, these should embrace hands-on laboratory experience, including observation and the conduct of experiments, as well as succinct communication by written and oral reports.

CAREER PATHS:

5. In order to offer the graduate a well considered career choice, the undergraduate program should assure students the opportunity for understanding the multiplicity of organizational cultures in which engineering is done, including the academic, the private enterprise, and the government service sectors. To achieve this goal, the faculty should be balanced with respect to their experience and familiarity with these sectors and cultures.

GLOBAL ENVIRONMENT:

6. The global nature of competitiveness in all spheres requires recognition that engineers must operate on a global basis. This, in turn, requires that engineering students have an opportunity to understand the multiple cultures of the world, especially those of nations creating technological advances. A working knowledge of a foreign language is desirable.

TEACHING PRACTICUM:

7. Graduate programs should include serious teaching practicums for all doctoral candidates as a core requirement.

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Engineering Education in the U.S., *continued*

As a corollary, serious industrial experience should be part of the experience of a faculty member.

CHANGING DEMOGRAPHICS:

8. To insure that the human technological resource base is adequate to meet the challenges of the next century, social justice and changing demographics both require that the participation of members of the under-represented groups, i.e., women, minorities, and the disabled, should be strengthened throughout engineering.

PROFESSIONAL CONSIDERATIONS:

9. Engineers in the private enterprise, government service, or academic sectors must assume responsibility for their engineering decisions. To help their students appreciate the far-ranging effect of these decisions, faculty should ascertain that the educational experience provides broad exposure to professional, ethical, social, economic, and safety considerations, as well as possible legal requirements for engaging in private practice or practicing engineering in other countries.

ACCREDITATION:

10. ABET should continue the development and use of accreditation procedures and processes to assure that all accredited engineering education programs are of acceptable quality. Further, ABET should use care in the development of these procedures and processes to assure that the diversity in engineering education is preserved and that programs that seek to satisfy the goals and objectives noted in items 1 through 9 above are supported and encouraged.

The National Science Board report, "Undergraduate Science, Mathematics, and Engineering Education," recommended that the National Science Foundation should provide leadership to enhance the quality of undergraduate education in engineering, mathematics and the sciences, and further recommended that the National Science Foundation establish programs to support this objective. The structure and the programs established by NSF in response to these recommendations are an excellent beginning. The Educational Activities Board and the United States Activities Board commend these steps taken by THE NSF and urge continued development of support for engineering education.

1991 VIDEOCONFERENCES

MARCH 20 - USES OF ARTIFICIAL INTELLIGENCE IN MANUFACTURING

Lead Presenter: Dr. Mark S. Fox

Remaining competitive in the world marketplace requires continual innovation on and above the factory floor. This program will cover applications of AI to decision making through the product life cycle, knowledge techniques, problem-solving architectures, and relationships between operation research and AI problem-solving techniques. Case studies will be presented.

APRIL 25 - APPLICATIONS OF FUZZY LOGIC

Lead Presenter: Dr. Lofti A. Zadeh

MAY 22 - USE OF NEURAL NETWORKS IN THE 90'S

Lead Presenter: Dr. James A. Anderson

SEPT 19 - QUALITY MANAGEMENT

Speakers from IBM & Cadillac

OCT 30 - SOFTWARE TESTING AND RELIABILITY

DEC 11 - TECHNICAL DEVELOPMENT & FUTURE OF OPTICAL COMPUTING

Robotics and Automation Society "Video Proceedings"

More than 300 conferences are held by IEEE each year, and many of these conferences would benefit by the use of visual media to document conference proceedings. EAD staff is currently supporting a project, spearheaded by the Robotics and Automation Society, which will address this requirement. As the President of this society, Arthur C. Sanderson, states, "Many of the new research and applications results in robotics and automation can be conveyed most effectively by video presentation of new devices and experiments."

The procedure involves soliciting video tapes of experiments and demonstrations. The selected tapes are reviewed by a video program committee. EAD is providing video production support to produce a composite tape of approximately two hours in length.

For further information please contact:

Peter K. Wiesner, Manager
Individual Learning Activities
Tele. (908) 562-5500
Fax. (908) 981-1686

FROM THE V.P.
LOOKING BACK ON 1990

Friends:

The year 1990 has been one of turmoil and progress. With the help of dedicated volunteers and staff; separate moves to restructure the IEEE, including doing away with IEEE-EAB, and to force termination of all EAB continuing education programs, were rejected at the Board of Directors level.

Progress was made in developing new continuing education materials, accreditation policies and practices, and curriculum surveys. Financial performance was reasonable despite some circumstances beyond the control of the EAB. The Engineering Skills Assessment Program has moved forward. Finalization of a joint entity statement on engineering education was the work of the EAB issues committee. This entity statement is included in this newsletter.

Another important part of EAB is its awards program. On October 3, the 1990 EAB awards ceremony took place and honored the following:

- 1990 Meritorious Achievement Award in Accreditation Activities was presented to Richard P. D'onofrio and George D. Peterson.
- 1990 Meritorious Achievement Award in Continuing Education Activities was presented to Eli Brookner.
- 1990 Major Educational Innovation Award was presented to Lionel V. Baldwin.
- 1990 EAB Meritorious Service Citation was presented to Lyle D. Feisel and Jerrier A. Haddad.

Despite the problems, I have enjoyed my work with EAB in 1990. The new friendships and the outstanding support of volunteers and staff have been truly appreciated. I have been elected to a second term as IEEE Vice President - Educational Activities. I look forward to working in that role in 1991 with all of you.

Dick Nichols

The INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS, Inc,
445 Hoes Lane, P.O. Box 1331 • Piscataway, NJ 08855-1331, USA

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