ENGINEERING EDUCATION IN THE 21st CENTURY

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- Editor

INTRODUCTION :

Forecasting the future has always been a risky business. Although futurology is now being considered a branch of Science, the accuracy of prediction depends on a large number of fuzzy parameters, the growth pattern of which is very difficult to estimate. Extrapolation of the present scenario along with anticipated change due to the system has served as well in predicting to a fair degree of accuracy the immediate future behaviour of systems as diverse as power load and energy demand, population growth, economic performance etc. However, it is almost impossible to predict the behaviour of a large system over a far distant future particularly when the system parameters indicate high rate of change. Engineering Education falls in this category of a system. I am sure readers will appreciate that at the beginning of the twentieth century one could not have anticipated that solid state physics, digital technology or fibre optics would be playing such an important role in the education of the present-day electrical engineer.

I am approaching the subject with great humility knowing fully well that the real shape of technology, engineering or engineering education which may exist towards the end of the twenty-first century could be beyond my comprehension or even beyond the comprehension of most living educationists today, All I propose to cover in this article is to identify the changes that are currently taking place and which would have implications on the educational system in the near and not too distant future. Since engineering education system is designed to meet the current and expected demands of trained manpower for solving social problems, the system has very intimate relation with technology, market complexity and dynamics, and society. We know that in today's scenario technology is changing so rapidly that the half-life of many known disciplines has dwindled to only 'a few years' and new disciplines are fast appearing on the horizon. Societal systems are in ferment in all parts of the globe, and economic liberalisation is affecting the market size and complexity as well as the norms of international trade. The case of mobility of professional across national borders has widened both the supply-demand perspective and the problem solving horizon making it imperative for educational planners to take a global view on both these counts and not be restricted to national considerations alone.

ANTICIPATED CHANGES :

Before discussing the scenario for engineering education, it would be worthwhile to list some of the changes likely to occur in the near future in Technology, Engineering and Society.

Some Expected Changes in Near Future

A. Technology

- Info Super highway
- Digital High definition Video / Audio Communications with large scale signal compression
- Virtual Reality Systems in Design, Marketing and Sales
- Nano Electronics and Large Scale Integration
- Al Operating systems in Control / Robotics Voice & Character Recognition
- Large Scale Expansion of Photonic Systems Including Lasers & Mili tary Use & Magneto-optical Syst-tem Development
- Bio Computing - DNA Computer
- Super Conducting Storage / Transmission / Transportation
- Fuzzy Controllers
- Large Scale Exploitation of Renewable Energies
- Clean energy From Fusion Reaction
- Microwave Transmission of Energy
- Thought Control Mechanism
- Advanced Genetic Engineering Techniques for Manipulation of Plants, Materials, Animals
- Human Genome -Coding-Decoding
- Artificial food
- Development Biology
- New Performance Materials
- Exotic Materials to Order
- Advanced Techniques for Resource Mapping Photo Interpretation
- Interplanetary Travel
- Safer and Faster Planetary Travel
- More Accurate Modelling & simulation of Engineering System
- Human-Independent Flexible Manufacturing Techniques.

B. Engineering

- Globalisation with Simultaneous Decentralisation
- International Competitiveness in Product / System Design
- Emphasis on Quality, Reliability, Productivity & Safety
- Intellect and Information as Capital Resource
- Concern for energy Environment
- Instant Access to Knowledge
- Reducing Time between concept to Marketing : Engineering - Concurrent / Simultaneous
- First Time Design Success : Emphasis on 3-D Simulation and Performance Evaluation on Models
- Multinational Engineering Work Force-Special Requirements of Compatability / Adoption
- Expert System Based Engineering Solutions

- In-built Technology Upgradation to Remove Obsolescence
- User Friendly Self Diagnostic Easily Maintainable Engineering Devices / Systems
- Large Scale Impact of Biological System Knowledge on Engineering System Design-Neural Networks, Biocomputing, Biomechanics, Bioelectronics, Biomaterials etc.
- Progressively more Dependence on Inter-and Transdiciplinary Effort in Engineering Solutions

C. Societal

- Globalisation Leading to Modernisation & Crosscultural Effects
- Market-Driven Economy
- Higher Disposable Income to Larger Numbers of People
- Nuclear Families
- Higher Literacy Rate, Higher Longevity
- Better Quality of Life
- Lesser Unemployment
- More Involvement of Women in Engineering / other Activities
- More Leisure for Non-commercial Creative Endeavour & Entertain
- Machine Replacing Human in Difficult Operations / Repetetive Work or High Precision
- A-1 Based Aids to Human Enterprise
- Concern for Environment / Sustainable development
- Increased Awareness of Human Rights
- War on Poverty and Inequalities
- Market Dominated Culture - Influence of Advertising
- Decreasing State Support to Both Higher and Technical Education
- Unsatiated Demand for Engineer ing Education at Least for the Next Two / Three Decades
- Alternative Delivery Modes for Education
- Importance of Engineering Profession may Gradually Decrease People being Attracted More to Financial, Commercial, Insurance, Media & Other Similar Profession

The above changes have basic implications on Engineering Education, some of which are easy to identify as follows :

Basic Implications of Anticipated Changes on Engineering Education

- Tacking Rapid Obsolesence in Engineering Knowledge / Techniques / Technologies
- Design Education in Multidimensional Societal / Global Framework
- Problem solving in Fuzzy Environment
- Promoting Creativity /Innovativeness in Knowledge-based Industrial Activities
- Processing Information / Data and Discarding What is irrelevent
- Evaluating Solutions for Local Relevance and Eco Friendliness
- Understanding Biological Systems and their Interface with Engineering
- Exploring Financial Resource Generation from Sources other that State Support
- Need for Stricter Quality Assurance in Market Controlled Growth of

Engineering Education

It would be appropriate at this stage to ask a very relevant question :

In view of globalisation, development of robotics, artificial intelligence and expert systems, autofault - diagnosis and modular construction / replacement, worldwide instant communication and access to knowledge / information, advance in molecular / cellular biology and growing numbers of genetic manipulations, and advances in materials to order, would we still need in future a large, highly educated engineering manpower ?

My answer to the question is an emphatic 'YES', because not only we will be living in a technology-dominated world but use and deployment of technology will affect all components of society, government, industry, universities, the general population, the health care system, and the environment etc. Moreover, the fight against poverty will continue in the next century and there is going to be a perceived shortage of engineers in most fast developing countries. The 'Engineer' would become the pivotal point in Industry and Society as a whole and would be needed for :

- Commissioning, maintenance and upgradation of technological systems;
- Developing new technologies for human use and happiness;
- Improving existing software for higher efficiency and developing a new generation of software;
- Accelerating economic development nationally / globally;
- Converting new scientific discoveries to marketable products; and for
- Exporting trained manpower to needy countries and co-operating in technological development world wide.

The need for 'Engineers' is strengthened by the fact that Engineering Education Develops innovative, creative and problem solving skills which are needed in all aspects of human endeavour. It is no surprise that almost half of the chief executives of the 50 of the world's largest corporations today have an engineering background.

ATTRIBUTES OF GRADUATES AND THEIR CURRENT PERFORMANCE :

The Arizona State University in the United States had a few years ago set-up a task force to identify the attributes of an engineering graduate and also the level of current preparation in the university to meet the desired output. The task force surveyed senior students', faculty, industry, alumni and their own members in grading the relative importance of ten selected attributes. The results of the survey are shown in Table 1. While problem recognition and solution was considered the most important attribute of an engineer by all groups, there was wide variation in the rating of other attributes. The low ratings for appreciation and understanding of world affairs and cultures and for business and management practices come as a surprise but perhaps the survey was done before globalisation had become so important. The same groups were asked to identify those attributes for which the current university education gives the preparation / performance ratings for other attributes. These are displayed in

Recent Survey of Attributes of an Engineering Graduate

Table I Importance of Attributes
(Task Force - Arizona State University
1991

		Seniors	Faculty	Industry	Alumni	T.F.
A	Problem Recog & Soln	1	1	1	1	1
B	Depth & Breadth in Tech skills	5	4	6	5	2
C	Maths. & Science Profiency	3	2	5	5	3
D	Communication Skills	4	3	2	2	4
E	Ethics & professionalism	9	6	3	3	6
F	Open mind, Positive Att.	7	7	3	4	8
G	Computer Literacy	2	8	9	8	7
H	Motivation & Cont - Learning	6	4	7	7	5
I	Bus & MGT Practices	8	*	8	9	*
J	Appr & Understanding World AFF & Cultures	*	9	*	*	9

Recent Survey of Attributes of an Engineering Graduate

Table II Importance / Performance in Satisfying Desired Outputs

		Seniors	Faculty	Industry	Alumni	T.F.
A	Problem Recog & Soln	2	3	7	4	4
B	Depth & Breadth in Tech skills	4	2	2	2	2
C	Maths. & Science Profiency	3	4	4	4	3
D	Communication Skills	5	8	8	8	5
E	Ethics & professionalism	8	5	5	7	8
F	Open mind, Positive Att.	7	6	6	5	6
G	Computer Literacy	1	1	1	1	1
H	Motivation & Cont - Learning	6	6	3	6	7
I	Bus & MGT Practices	9	6	*	*	*
J	Appr & Understanding World AFF & Cultures	*	10	9	9	9

Table II. While there was unanimity that performance level was highest for Computer literacy and usage, the perception of the various groups differed widely in many other areas. Industry appears aggrieved that graduates coming out of the university system have very low ability in problem recognition and solution, and in communication skills. Industry's concern for low communication ability of engineering graduates is shared by faculty and alumni. A comparison of Tables I and II shows that while computer knowledge and usage are overperformed, there are serious shortcomings in the preparation for problem solving (Design) and communication skills as compared to the requirement.

DESIRABLE CHARACTERISTICS OF THE ENGINEER OF THE FUTURE :

The Arizona State University Task Force had indetified ten attributes of the present day engineering graduates. Expanding these to include the effects of changing international economic scenario and the challenges of emerging technology, one can list the desirable characteristics of the Engineer of the future as some one who would possess :

Desirable Characteristics of the Engineer of the Future : He / She should Possess

- A Breadth & Depth of Technical Background in his area of Specialisation
- A Fundamental Understanding of Mathematics, Physical & Biological Sciences
- Some Knowledge of Business Strategies & Management Practices
- Problem-solving Skills
- Innovative and Creative Abilities
- Proficiency in Using Tools of Analysis, Synthesis, Optimisation, Modelling & Simulation
- Communication Skills Both Oral and Written and Ability to Persuade Policy Makers to His / Her Point of View
- Ability for Technological Assessment/ Adaptation Upgradation / Transfer
- Capacity and Willingness to Learn and Keep Learning
- Integrity of thought and Action-Values with High Ethical and Professional Standard
- A Global Perspective in Engineering Activity
- Awareness of Parameters of International Competitiveness-Quality, Reliability, Safety, Productivity, Cost-Effectiveness
- Understanding of Impact of Engineering Activity on Society / Environment
- Capacity to Work in Interdisciplinary / International Engineering Team
- Appreciation & Understanding of World Affairs & Culture

GRADUAL CHANGES IN ENGINEERING EDUCATION :

Engineering Education has undergone many conceptual changes since its establishment as a discipline of serious study, innovation, and research after the industrial revolution. In the Nineteenth century, the emphasis was on innovation and personal ingenuity. The education and training in this period are "HOW" dominated and the efficacy of education and training depended a great deal on the personal skill of the trainers in operating, manipulating and developing new machines, and gadgets. The 'Twentieth' century brought in an attitude of scientific analysis involving engineering systems, and education became more "WHY" dominated, more science-based. Innovations were still important, but problem solving became more and more science based. The 'Twenty-first' century is threatening to be dominated by information processing and computer simulation. Education training will not only worry about "WHY" but also "WHY NOT" and " HOW BEST".

To illustrate the dynamics of technological changes, let us take a quick survey of dominating events in the field of electrical engineering in the nineteenth and twentieth centuries and some pointers for the 21st century.

Dominating Events in Elec. Engg.

19th Century :

- 1831 Faraday Discovers Electromagnetic Induction
- 1879 Edison Invents Incandescent Bulb
- 1888 Tesla's Induction Motor

Birth of Power Industry

20th Century :

- 1873 Maxwell's Treatise on E & M
- 1897 Thomson's Discovery of Electron
- 1899 Marconi's Demonstration of Wireless Communication
- 1906 Triode by Deforest; Practical Radio by Armstrong
- 1930 Practical Television Systems IBM Mark I Computer
- 1947 / 48 Transistor, (Bardeen, Brattain & Shockley) - Bell Telephone
- Kilby & Noyce Invent the IC-Microprocessor
- 1959 Ruby Laser
- 1960 Gas Laser
- 1961 Semiconductor Laser
- 1980 Optical ICS Announced

Birth of Modern Electronics, Computer & Communication Industries

Age of Electronics, Communication & Computers

21st Century : The Information Age

Earlier Information Industries

Invention	Industry
Printing Press	- Publishing
Electric Battery	- Telegraph/Telephone
Film	- Photography /Cinema
Electronics	- Broadcasting / Cable
Computer	- Data Processing
Laser / Fiber	- Broadband Systems

Next Century all the above six info Industries will be Electronic / Computer Based as the Boundaries get Blurred. When 8-Bit Microprocessor was invented nobody thought there was market for 32-Bit 1MIP Processor. They thought microprocessor was a calculator-not an Information system 100 MIP Processors and 1GB Dynamic Memories are round the corner-market driven.

Software Requirements in Speech and Character Recognition, HDTV, Video on Demand, Complex Simulation, Teleconferencing, Intelligent Systems and Virtual Reality will Demand more Processing Performance and Greater Storage.

Nanofabricators of IC will be Constantly Challenged

Old Information Industries may die and New Players will be Under Groups

- Generation and Production of Information
- Transmission Networks
- Information Processing Systems
- Information Storage Systems
- Display Systems

CURRENT DEFICIENCIES IN THE PREPARATION OF INDIAN GRADUATES :

The survey mentioned in Sec. 4 refers to American graduates and does not fully represent the Indian educational scene. In my opinion our graduates show deficiencies in the following areas:

Current Deficiencies in Preparation for Indian Graduates

- Prob Solving & Design
- Communication Skills
- Motivation for Life-Long Learning
- Professionalism & Ethics
- Management Inputs
- Inter Personal Interactions
- Computer Usage
- Maintenance Philosophy & Attitude
- Entrepreneurial Ability

Some other deficiencies, emerging due to advancement taking place in technology and engineering and to the changes in the global market place, can be identified :

Emerging Deficiencies

- Training in Biological Systems
- Simulation Theory & Practice
- Quality Consciousness
- International Competitiveness
- Inter-and Trans-Disciplinary Approach
- Ability in Technology Assessment transfer / Adaptation
- Global Perspective
- Training in Information Retrieval

CHALLENGES FACING HIGHER TECHNICAL EDUCATION IN INDIA AND POSSIBLE SOLUTIONS :

While talking about the future, it would be unwise to neglect the present. I feel our engineering education system is facing a number of major challenges and hardships which need identification and steps for alleviation. I have listed some important ones as below :

REGIONAL IMBALANCE IN CURRENT FACILITIES :

While the number of institutions offering engineering degree education has shown a remarkable rise as shown in Table below, the current regional imbalance is starting. The five southern

Challenges Facing Higher Technical Education & Possible Solutions

1 Large Scale Expansion	:	Quality Assurance System
2 Obsolescence of Faculty	:	Continuing EDU made Compulsory Co-operation with Industry Higher Degrees
3 Curriculum Design	:	Model AICTE Curriculum Revised Drexel's E[4] Program Relevance Determination National Board of Accreditation
4 Demand Increasing With Facilities Decreasing	:	Distance Education, Mode-Development & Expansion
5 Resource Crisis	:	New Methods of Resource Generation
6 Library Facilities Upgradation	:	Inter Library Cooperation, Internet / Inflibnet, E-Mail
7 Lab Facilities Upgradation	:	Cooperation with Industries Networking Institutions
8 Computer Facilities Upgradation	:	University LAN / MAN / WAN
9 Management Transformation	:	Democratisation Planning Transparency in Evaluation/ Promotion, Fostering Academic Atmosphere, Encouraging Excellence
10 Interaction with Others	:	Participating in National / International Conferences / Competition Better industry Interaction.

states have created facilities for nearly half the total of engineering admission intake capacity while Eastern states appear to have the poorest facilities. This disparity will have to be reduced in future so that there is equitable development of trained power in the country.

Expansion of Engineering Education

A. University Level Institutions

Year	Number	Intake
1940	11	600
1947	44	3200
1961	113	15600
1971	139	18200
1980	157	28500
1986	287	59500
1990	337	66580
1994	370	87530

Expansion of Engineering Education

B. Regional Distribution

1994

Region	Degree Institutions	Intake
Southern (Andhra, Tamil Nadu, Pondichery)	89	21,047
South Western (Karnataka, Kerala)	61	21,514
Northern	64	10,044
Western	124	28,654
Eastern	32	6,282
Total	370	87,532

CHANGING EDUCATIONAL SCENE

Operation	Current	Future
Admission	Restricted	On Demand
Fees	Low Controlled	High Market-Driven
Mode	Class Room Lectures	Wired Homes with Interactive Video
Assistance	Tutorial	E-Mail, Electronic Bulletin Board
Laboratory	Lab. Classes simulation	
Design	Design Lab	Computer Assisted Virtual Reality Work
Group Activity	Physical Assembly	Teleconferencing
Industrial Trg.	Work in Industry	Work in Industry
Assignment	Paper Work	Electronic Submission
Evaluation	Exam. Papers Lab. Exercises	Question Banks Self-Evaluation on Design Project Simulated Design and Lab Exercises
Degree Award	Passing Reqd. Credits	Amassing Reqd. Competencies

The first and fundamental requisite in the ideal Education of young engineers, A Broad, Liberal Education in Philosophy & Arts, is a precedent to the Purely Professional Training. The Main Purpose should be such a Cultivation of Human Qualities as will enable engineers to meet men as well as matter.

The second fundamental characteristic of the ideal Education in engineering a Through Training in what may be termed the Natural Philosophy of engineering, which embraces all that body of Mathematical and Scientific knowledge constituting the Pure Theory of and engineering Operations... This Feature of an engineer's Educational Training is as Profoundly Practical as it is Profoundly Theoretical...

As no course of Professional Study can possibly fit a student for a complete and mature professional practice, it is safe assumption that even "ideal Engineering Education"

Cannot be expected to produce young engineers so mature in the exercise of all these Professional Functions that nothing is left for the years of subsequent practice to accomplish in the direction of education.

Prof. William H. Burr 1933

ASEE - 1st MEETING

CHANGING EDUCATIONAL SCENE :

All educational processes and operations are undergoing some changes and many more changes are expected in the near future. Some of these are indicated below :

The Education system is known to be very conservative and changes in education occur very slowly. Large institutions like universities change even more slowly. There is however a general maxim which rules under this situation "Old Institutions either change or new ones emerge to take their place to meet Society's needs." Globalisation, information technology, genetic engineering and new materials are making the pace of change increase dramatically. Engineering Education must move more quickly to meet the emerging challenges of the 21st century.

CONCLUSION :

I would like to conclude by quoting from a lecture given by Prof. William H. Burr at the first meeting of the Americana society for engineering Education (ASEE) in 1893 i.e. about hundred years ago.

The points made by Prof. Burr is as valid today as they were a hundred years ago. This underlines the fact that the philosophy of engineering education does not change with time, and hundred years from now we may still be emphasising the same points.

THE MORE WE CHANGE, THE MORE WE REMAIN THE SAME.

REFERENCES :

1. "Attributes of Engineering graduates and their Impact on Curriculum Design" by Evans, Beakley, Eouch & Yamaguchi Journal of Engineering Education ASEE, Vol. 82 No. 4, Oct 1993.
2. "Engineering Education - A Century of Opportunity" by L. K. Monteigh I bid. centennial Issue Vol. 83, No. 1 January 1994.

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