DEMANDS OF A TECHNOLOGICAL SOCIETY

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- *Editor*

PRIMITIVE MAN TO THE TECHNOLOGICAL MAN

The human march from the primitive human through the stone age, the bronze age, the iron age, the industrial revolution to the technological age has been characterized by decreasing dependence on musclepower and increasing use of energy from other sources. The primitive man used only musclepower; the agricultural man depended on animal power and slavery in addition to his own musclepower. The use of machines rather than muscles has been a hallmark of the industrial man; but the technological man has become dependent on both machine power and computer power. It is appropriate to quote Oscar Wilde in this context :

"The fact is that civilisation requires slaves, the Greeks were quite right there. Unless there are slaves to do the ugly, horrible, uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure, and demoralising, on mechanical slavery, on the slavery of the machine, the future of the world depends." (Oscar Wilde-1895)

Similar views were expressed by Dr. Homi Bhabha in his presidential address to the First International Conference on Peaceful uses of Atomic Energy held in 1955 in Geneva :

"In a broad view of human history," "it is possible to discern three great epoches. The first is marked by the emergence of the early civilizations in the valleys of the Euphrates, the Indus, and the Nile; the second by the industrial revolution, leading to the civilization in which we live; and the third by the discovery of atomic energy and the dawn of the atomic age, which we are just entering. Each epoch marks a change in the energy pattern of society....... It is sometimes forgotten that all the ancient civilisations were carried on the muscle power of slaves or of a particular class in society. Through the very limitations of the available energy, the fruits of civilisation could only be enjoyed by a few.."

INDIA, A COMBINATION OF AGRICULTURAL, INDUSTRIAL AND TECHNOLOGICAL SOCIETIES

Notwithstanding the advances made in many parts of the world which

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could be considered to be in a state of growth between the industrial society and the technological society, muscle power of slaves or a class of people are still used as a source of energy. Based on these consideration, we may consider that the present day India is part agricultural society, and part industrial society with pockets of technological society here and there. I shall amplify this point by considering some of the indices for technological development.

INDICES TO MEASURE GROWTH

There are many indices with which the industrial and technological growth of nations could be compared. The per capita electricity generation is one such (Table 1). The value for India is 350 KWh per annum whereas for United States it is as high as 12000.

The total installed capacity for electricity production today in India is only 77 GWe. It is estimated that in India a total energy equivalent of 25-40 GWe is utilised for various applications from the musclepower of both animals and humans. The use of energy from biomass and (firewood, cowdung) is also widespread particularly for cooking purposes; in 1987, about 0.16 GTe of fuel wood (energy equivalent of 60 MTOE) was consumed in India which was 43.33% of the total fuel consumption of 1.2 GTe fuel wood in the whole world that year. The energy from fuel wood was to account for about 40% of India's total energy needs.

Table 1 Per Capita Electricity Generation World Scenario

Country / Region	Per Capita Electricity Generation KWh per annum
India	350
World average	2100
Western Europe	5000
North America	12000

LOW GROWTH, LOW DEVELOPMENT, LOW PRODUCTIVITY

The consumption of steel is another index; here our rate of 25 kg per capita is to be compared with 250 kg. per capita for the most advanced countries. In human development index (HDI, a composite index which measures human development, by combining indicators of life expectancy, educational attainment and incomes) we are ranked 135 among the nations of the world; even nation like Sri Lanka (90), Philippines (94) and Indonesia (105) are ahead of us. When we compare the Gross Domestic Product per employed person also, we come at the lower and with a figure of US Dollars 838, Whereas the index for Japan is 71,713, Germany 61,455, France 59,103, USA 50,343 and Republic of Korea 15,651 - (1992 figures). Note that the index for Philippines is 2194, (Table 2).

HUMAN RESOURCES FOR A TECHNOLOGY SOCIETY

The transformation of India into a technological society therefore essentially implies increasing the per capita electricity production to at least 2000 kWh, steel production to at least 100 million tons per annum and achieving similar growth in all sectors of infrastructure and industry as early as possible. Not only the total Gross Domestic

Table 2 Gross Domestic Product per Employed Person for some Selected Countries							
Year	Country						
	Japan	Germany	France	USA	India	Philipines	Republic of Korea
1980	18717	31747	22776	26172	700	2069	4250
1985	22821	23288	20924	36930	759	1607	5811
1990	60814	52208	54163	45730	971	1946	13294
1992	71713	61455	59103	50343	838	2194	15651

Product has to multiply tenfold or more, but the productivity per employed individual also has to make a quantum jump. The question I am posing (and trying also to give an answer) is what kind (quality and quantity) of human resources is needed to achieve this transformation and how should we orient our engineering and technical education to meet the demands of a technological society in 21st century India ?

PRESENT STATUS OF ENGINEERI - NG AND TECHNICAL EDUCATION IN INDIA

Science and Technology Education in India

An often repeated statement is that India has the third largest number of scientific and technical personnel in the world. It has also often been lamented that in spite of this, our achievements in Science and Technology have been meagre. These two statements need close examination. Table 3 shows the statistics available regarding the stock of Science and Technology personnel by broad fields of specialisation in India; total figures for the end of every decade since independence is given. One point to note is that the numbers relating to natural sciences pertain to all those who have completed a Bachelor's degree in science. It is well-known that it is not the case that all those who complete a Bachelor's degree in science or even a Master's degree do not end up in having a career in science and Technology; a large fraction of such personnel, though qualified in science are found to end up in a career which has nothing to do with science likes jobs in banks, insurance companies, offices of commercial establishments, state/central governments etc., Even ignoring this fact, the total of 3.8 million educated in science and technology for a population of 840 million give us a figure of 4.5 per thousand of population; this density is to be compared with the index for the erstwhile USSR (100) and Japan (180). The two countries that are ahead of India in the total stock of science and technology personnel.

Available data on scientists, engineers and technicians per thousand of population for few chosen countries are shown in Fig. 1. and Fig. 2 provides more recent and more telling information on the number of scientists and engineers engaged in research and development per thousand of economically active population in some selected countries for the latest year for which both parameters are available. The index is 10.2 for Japan, 9.9 for former USSR, 7.6 for USA and 0.4 for India. Other revealing information on national expenditure on R & D for a few selected countries are shown in Table 4.

It is clear from the above statistics that industrial and technological advancement of a country does not necessarily depend on the number of science and technology personnel, but more on their density (i.e. number per population) and the expenditure on R & D as a percentage of the GNP.

ENGINEERING EDUCATION IN INDIA

After this digression on science and technology and R & D let me get back to reviewing the present status of engineering and technical education in India. Here again, I would like to look at the available statistics. Engineering education is generally pursued in India at two levels; a four year course after Higher Secondary School leading to a Bachelor's degree and a three years diploma course after Secondary School. Training in engineering trades are imparted at the industrial Training Institutes (ITIs) which conduct courses of 12 to 18 months.

WHERE ARE THE SKILLED TECHNICIANS ?

Some observations on the information available in Table 5 are relevant. One is that information is not readily

Table 3 Stock of Science and Technology Personnel in India

FIELD	Number in Lakhs				
	1950	1960	1970	1980	1990
Natural Sciences	0.76	2.13	5.60	9.68	21.04
Medicine	0.51	0.76	1.25	1.68	3.20
Agricultural Sciences	0.08	0.24	0.61	0.97	1.96
Total Sciences	1.35	3.13	7.46	12.33	26.20
Degree Holders in Engineering	0.22	0.62	1.85	2.21	4.54
Diploma in Engineering	0.32	0.75	2.44	3.30	7.35
Total Engineering	0.54	1.37	4.29	5.54	11.89
Total Science & Engineering	1.89	4.50	11.75	17.87	38.09

Table 4 Expenditure on R & D for some selected countries. Figure in brackets indicate the year for which the information pertains to duration; there is also the national apprenticeship scheme under which or the job training in technical skills are provided at various industries.

Country	Expenditure on R&D at current price (Million US Dollars)	Expenditure on R&D at constant price (Million US Dollars)	R&D Expenditure as a percentage of gross National Product
USA (1988)	139255	82476	2.9
Japan (1988)	82931	42225	2.8
Germany (1987)	31854	25667	2.9
France	21929	18020	2.3
Republic of Korea (1988)	3209	2393	1.9
India (1992)	1706	1760	0.83

* Available information on the growth of technical education in India including post-graduate studies is given in Table 5.

available on the training of craftsmen/ technicians. According, to J. C. Agarwal in 1988, 291 million people were employed in India of which 50 million were in engineering sector. The number of diploma holders and degree holders in engineering in 1988 would have totaled about 3.5 million (Table 3). It is reasonable to assume that five percent of the total i.e. about 2.5 million may be carrying out the non-technical functions. This would give a total of about 44 million craftsmen/technicians employed in India in the year 1988. The statistics given in Table 5 would not account for such a large number. What this implies is that the training of technicians and craftsmen through the industrial Training Institutes and the Apprenticeship programme of the Ministry of labour is providing only a small fraction of the technical workforce in the country. It is also a fact that many organisations like Dept. of Atomic Energy, Dept. of Space, Defence Research & Development Organisation, Railways, Defence Production (Ordinance Factories) etc. in the Government have training programmes that provide on the job specialised training of a very high quality to the technicians. Similar

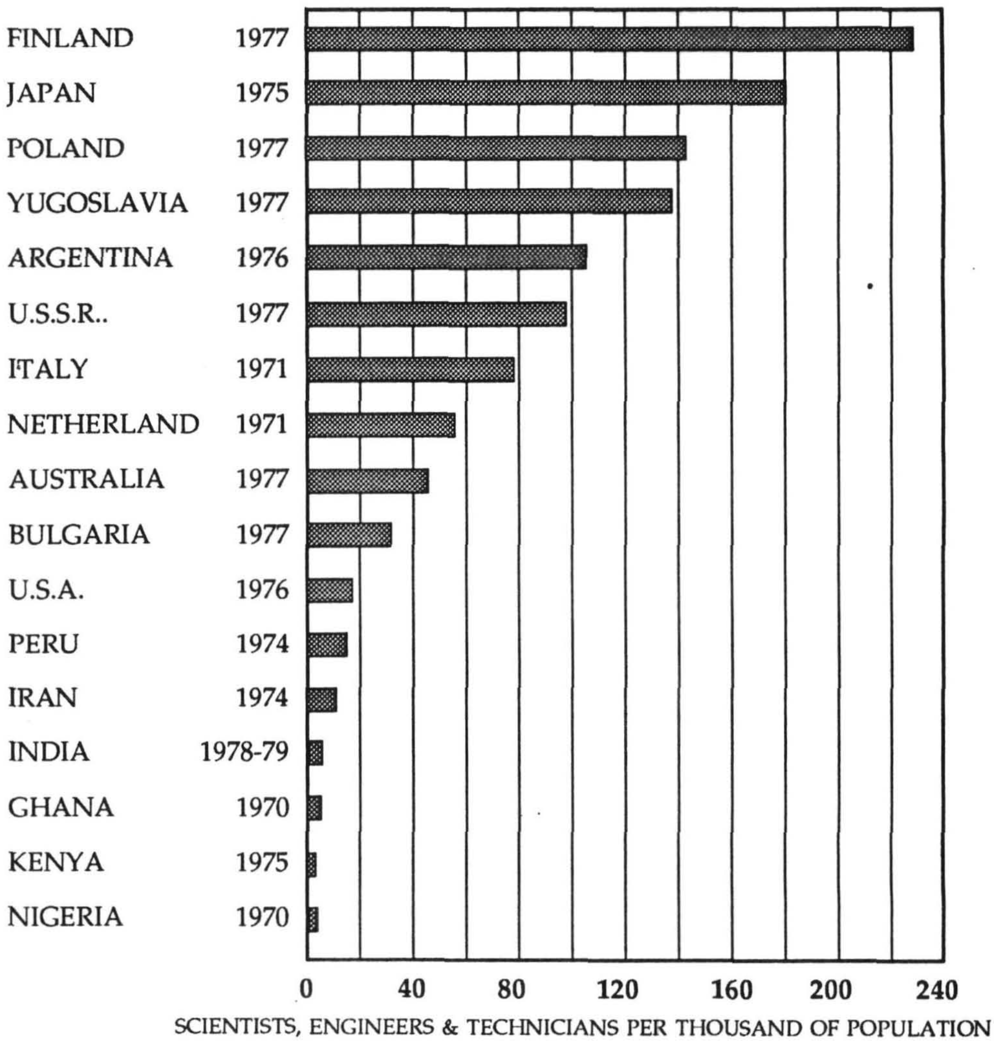

Fig. 1 : Scientists, Engineers and Technicians per thousand of population for selected countries. (For India data for 1978-79 and for other countries data available for nearest year as indicated)

training programmes are also organised by many private industries. Just to mention a few, the programme in the L & T Group and the G. D. Naidu Group (Coimbatore) of industries are well-known to produce high quality technicians. Another well-known training programme is that of the Nettoor Technical Training Foundation (NTTF) which provides all-round training in tool room activities, spreading over three years. In fact this programme is supposed to be

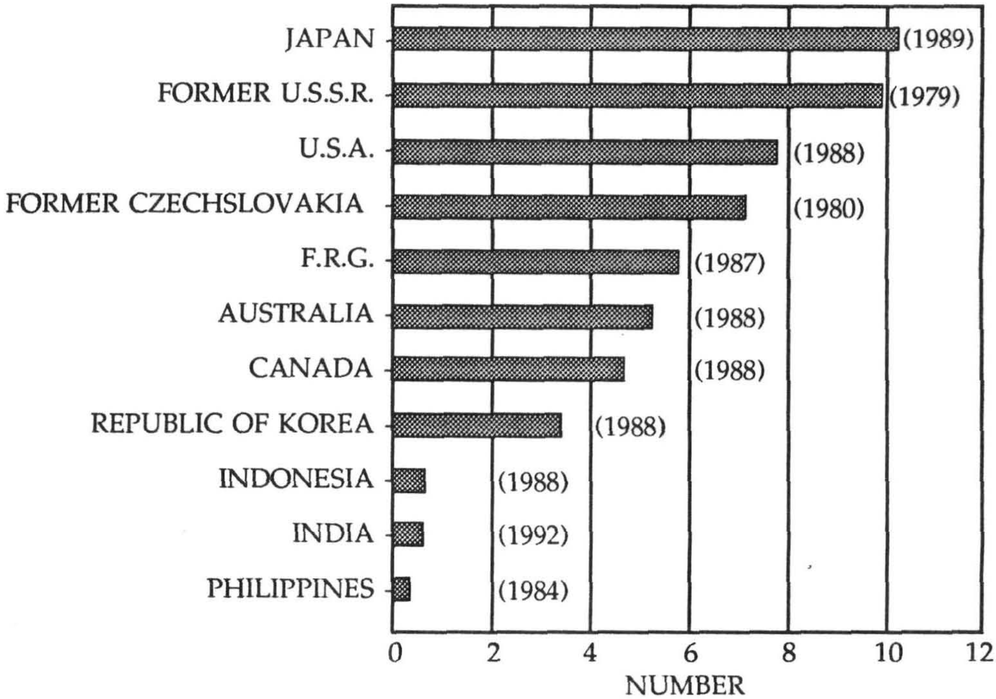

Fig. 2 : Scientists and Engineers engaged in research and development per thousand of selected countries for the latest year for which both the parameters are available. (S + T Pocket Data Book 1993, Dept. of Science and Technology, New Delhi.)

superior to the diploma course offered by the Polytechnics. The market value of personnel trained in some of these programmes is very high and one tragedy is that many of them ultimately end up working not in India but in Gulf countries. Another observation is that the ratio of graduate engineer to diploma holder to skill technician is very unfavorable for the technological growth of the nation. To a large extent this has happened because the responsibility for training of engineers at degree and diploma level have been entrusted to All India Council of Technical Education whereas the training of skilled technicians has been in the purview of the Ministry of Labour and Employment. This is not a happy situation for coordinated and planned growth of human resources development for a technological nation. The imperatives of modern technology demand not only engineers and scientists but also abundant supply of technical labourforce that can constantly be-retrained and taught new techniques. As the recent OECD report on Technology and Economy points out, the absence of sufficient number of qualified technical personnel, makes the

Table 5 Growth in Technical Education in India

Year	Training of Craftsmen/ Technicians			Diploma in Engineering			Bachelor's Degree in Engineering			Me./M.Tech.	Ph.D.
	No. of ITIs	Capacity of ITIs (Number	National Apprentice Scheme	No. of Polytechnics	Intake	Output	No. of. Engg. Colleges	Intake	Output		
1950				86	5,903	2,478	49		4,119	2,198	
1955	59	10,500		114	10,484	4,499	65	5,888	4,917		
1960	132	42,000		197	24,020	10,397	97	13,165	5,310		
1966	250	55,000	14,000								
1973				307	37,000 [50,000]*		138	20,000 [27,000]*			
1974									15,043	1,984	266
1984									21,963	2,681	464
1985	1,268	1,80,000 [2,40,000]*	1,30,000								
1987									28,345	4,465	603
1988									27,894	4,306	573
1989									28,927	4,560	560
1993	-	-	-	500	80,000		200	40,000			

* The number in brackets is the actual capacity. In 1973, intake to polytechnics and engineering colleges were deliberately restricted in view of the employment situation. In 1985, through the capacity of the Industrial Training Institutes was 2,40,000 only 1,80,000 could be admitted as there were not enough applicants, this trend is just

difference between the industrialised economics and the developing countries. In future, more and more, the capacity of the labourforce to absorb new learning will determine the growth prospects of the economy. In this context, there is need to reorient the training of a technician such that he is adept at a number of a highly skilled trades and can switch from one to another depending on the need of the day. Such people will also be able to undergo on the job refresher courses and re-training to learn new and advanced techniques. I am aware of a programme for training and human resources development for technical personnel carried out at L & T Works at Hazira where this concept of training in and practicing multiple trades has been successfully carried out. It is also necessary to go beyond the traditional trades like fitting, machining, welding etc., to new techniques hitherto not introduced. Orientation of our programmes for technicians' training in future in this direction, in my mind, is crucial because in the next century, the presence of a large number of technical personnel at the working level - not just scientists and engineers - is going to transform a developing country to a technological one.

POST-GRADUATE EDUCATION IN ENGINEERING :

Another observation from Table - 5 is the stagnation of engineering education at the Post-Graduate and doctoral level. This is a problem not unique to our country but is universal. Unless the market value along with the utility of M. E. / M. Tech. and Ph. Ds in Engineering are drastically changed, this situation will continue. But this does not auger well for the growth of a technological nation. Today we produce about 600 Ph. Ds every year in engineering and about 4000 in basic sciences. This is similar to the proportion of about 10 ph. Ds in basic sciences to four Ph ds in engineering that prevail in the US today; S & T leaders in USA have found out that the situation in Japan is just the reverse : 10 Ph Ds in engineering for four Ph Ds in basic sciences. The difference in this proportion has been highlighted as one of the reasons this and change the attractions for a post-graduate education in engineering really rewarding. Today when the best graduate engineer is able to attract a salary of Rs. 6,000 - 10,000 p.m. it is ridiculous to expect that motivation alone can propel an engineer to pursue post-graduate education or research on a monthly stipend of the order of Rs. 2500/- p.m. Further after obtaining M. Tech. or Ph. D. he often finds that in industry there is no increase in his market value. Post-graduate education and research in Engineering in the technological creativity; the best engineering minds have to be attracted to this area. People trained at the post-graduate and doctoral level should also be found in abundant numbers in the industrial environment. Changes in these directions are urgently needed and cannot be left to forces of market pull and push. Government and industry have to take deliberate decisions to promote conditions that can ensure the changes required.

DIPLOMA EDUCATION IN ENGINEERING :

As far as the diploma education is concerned the government has recognised the need for revamping the system. A programme has been launched with the assistance of World Bank to enable the State Governments to upgrade the polytechnics in capacity, quality and efficiency. The project estimated to cost over Rs. 1650 crores including the World Bank credits / loan assistance of grant of half a billion US dollars over the period 1990-1999 would cover almost all the Polytechnics in the sixteen states and one in the union territory. This programme is being implemented with the active participation of experts from Canadian community colleges.

At this stage, I would like to examine an argument that is often heard that in the Indian context, the diploma engineering education is irrelevant. It is stated that many engineering industries are of the view that they recruit diploma engineers. In my opinion, supervisors are an important arm of the management and it is necessary that at least a good fraction of the supervisors are directly recruited and all of them do not come from the shop-floor technicians level. While opportunities for senior technicians to reach supervisory cadre by promotion should be retained, the need for diploma holders at supervisory level would continue. In many high technology activities like space and atomic energy, the technology team consists of three tiers - Scientists / engineers, Scientific and Technical Assistants at Diploma level and the Technicians and this is a useful combination of theoretical and practical skills. The brightest among the diploma holders would also acquire knowledge and qualifications appropriate to a degree and can go to higher levels of management. The polytechnics have produced many good engineers some of whom have even reached top levels of Industry. It is also a fact that many small scale industries employ only diploma engineers; this is invariably the case when a small company is owned by an engineer - entrepreneur. In my opinion therefore, polytechnics will continue to have a due role in our country and the decision to revamp them is in the right direction.

ENGINEERING EDUCATION AT THE DEGREE LEVEL :

The Debate in the U.S.

Having looked at the training of technicians and at engineering education at the diploma and post-graduate levels, it remains to examine the status of engineering education at the degree level. While doing this, I would like to first focus on the debate that is going on in the USA about engineering education in general. Engineering education, particularly in the higher status Universities in the US has been criticised to have such a large content of the sciences, theory and mathematical analysis at the expense of design skills and manufacturing technologies, that the graduates have been trained to attempt only single answer problems. A study by the Massachusetts Institute of Technology reported that "men trained at" second-rate schools" were often found to be, more willing to attempt solution of whole problems that those trained at "first rate schools" and worked into positions of leadership whence they directed the work of those from the better schools." this statement gives a feeling of 'deja-vu' to us in India where we find more graduates from Roorkee, Poona Engineering College, Banaras Hindu University, Bengal Engineering College, College of Engineering at Guindy (Madras), Victoria Jubilee Technical Institute, Bombay, PSG College and Govt. College of Technology, Coimbatore, the Regional Engineering Colleges (RECs), Engineering College of Bangalore, Delhi, Trivandrum and a host of other towns from all over India in important positions in industry, research, Government and in the academia than from the more prestigious Indian Institutes of Technology (IITs)

THE IITs HERALD SCIENCE - BASED ENGINEERING IN INDIA :

I have focussed attention of the IITs

and contrasted them with the more traditional colleges of engineering and the RECs with a deliberate intention. Because, with the advent of the IITs in India, our engineering education came to be influence by the fads and fashions prevalent in USA. Lest I be, accused of maligning the IITs, let me state my viewpoint by quoting a former director of IIT, Madras, Professor L. S. Srinath :

"It was IIT-Kanpur, which came into existence in the late fifties with the collaboration of a consortium of ten leading American Institutions, that introduces a new curricular structure with a heavy science base to engineering education. 'Science-based engineering,' 'knowledge of know-why is better than merely a knowledge of know-how.' etc. became the catch words. With the slow induction of computers and introduction of engineering science subjects (like mechanics of solids, mechanics of fluids, electrical sciences, materials science systems dynamics, etc.), engineering education began to assume a more glamorous front. Traditional workshop practices, engineering drawing, industrial training, etc., began yielding, making way for the introduction of newer courses. Still, one should give credit to IIT-Kanpur, since there was a strong conviction that design, which is the essence of engineering , should find a prominent place in the curricula, and hence design engineering was made a compulsory subject for all branches of engineering. And this subject, i.e., design engineering - whose aim is to teach students how to tackle open-ended problems, which do not have unique answers, but multiple answers, out of which one has to judiciously select the most appropriate ones keeping in mind the severe constraints that prevail in a given environment - was carefully built into the curricula. However, in spite of its tremendous importance in engineering education, as curricula underwent changes after every few years, the design-oriented courses soon found their way out, and today the engineering education has became a second-rate science education resembling more an applied-physics course, and completely devoid of its characteristic features and identity."

AN ANALYSIS OF RESEARCH METALLURGISTS IN A MAJOR CENTRE INDIA :

The above is indeed a strong indictment, but one may very well ask "why worry about this, when only about 2000 of the total 40,000 engineers produced in India in a year come from the IITs ?" True and correct, also since anyway depending on discipline and the IIT, 25 to 55% of these graduates leave the country for good. I also demonstrate through table 7.

There are many interest observations that can be made on the information in Table 7. One is the multi disciplinary nature of a modern R & D team. Another is the large proportion of Ph. D's and M E / M Tech. A third interesting factor is the cross-breeding in specialisation - Six of the Ph. D's, are for one Physicist, one mechanical engineer and four chemists but in Metallurgy / Materials Science one electrical engineer, two chemists and two mechanical engineering have done a Master's in Metallurgical engineering. Three of the chemists and the one mechanical engineer who have a Ph. D. in Metallurgy, first

Table 7 An Analysis of Scientists and Engineers in the Metallurgical Laboratories of INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH, KALPAKKAM

IGCAR has three metallurgical Divisions which together employ 89 engineers/ scientists who have their first basis qualification in

Metallurgical Engineering	46	(13 Ph. D., 10 Masters)
Physics	19	(2 Ph. D.,)
Mechanical Engineering	12	(1 Ph. D., 3 Masters, 2 LME)
Chemistry	12	(6 Ph. D., 2 Masters)
Electrical Engineering	3	(1 Masters, 1 LEE)
Electronic Engineering	2	(1 Masters)
	94	

46 Metallurgical Engineers

		Ph. D.'s	
IISc Bangalore	12	IISc	8
RECs	13	Madras University	7
AMIIM/AMIE	7	IIT, Madras	3
Calcutta	3	IIT, Kanpur	1
Roorkee	2	IIT, Kharagpur	1
Poona	2	Bombay University	1
Bharatiyar (Coimbatore)	2	IIT, Delhi	1
IIT	2		
Others	3		
Total	46	Total	22

MS/ME/M.Tech.	
IIT, Madras	14
IIT, Bombay	3
I.I.Sc.	2
IIT, Kanpur	2
IIT, Kharagpur	1
US	2
Total	24

took a Master's degree in Metallurgy. The strong input from IISc, Bangalore which is a long tradition from the days of Professor Brahm Prakash may be noted.

A few years ago, I presented a similar analysis at a conference on metallurgical education and research with the title "who does metallurgical research in India." A professor of IIT got up soon after my lecture and said : "This is a deliberate attempt to malign the IITs." Before I could answer, another Professor also from an IIT in the audience started defending me : Dr. Rodriguez is absolutely right. In fact, if we look at who comes to IITs for post-graduate education and training we will have a similar data; all from other colleges." In my opinion for human resources development in India IITs' contribution has been in post graduate education. It is stated that 60% of M. Techs. and 75% Ph. D's in India are produced by the IITs. In IGCAR, Metallurgy Group, 20 out of 24 Master's degree and 6 out of the 22 Ph. D's are from IITs. IIT Madras could have had a larger share of the Ph. D's but for its insistence on two-semester residence for external candidates. This is only one semester for other IITs and none for Madras University. (As a recognised research centre of Madras University, IGCAR candidates carry out the required course work and methodology examination at the Centre itself).

A PARADIGM SHIFT TO DESIGN SKILLS, KNOW-HOW, SYNTHESIS AND INTEGRATION :

Before proceeding further, let me assure those who are products of IITs or otherwise associated with them and also my numerous friends from the IIT system, that in whatever I have said, there has not been any intention or attempt to belittle or denigrate the IITs. Paradigm shifts are needed periodically in any society, structure or organisation. In the 50s and 60s, in engineering education, the paradigm shift in US and India was towards and emphasis on science, mathematical analysis and reduction and know why of things. The time has come for a shift back to the traditional engineering skills, to know how to synthesis and integration and to stress on complexity and uncertainty along with the non verbal feel for physical behavior and common sense judgement. In making this shift, we are only recognising that all of our technology has a significant intellectual component that is both non-scientific and nonliterary; it is characterised by visual thinking which involves images and perceptions, the stock-in trade of the artist, not the Scientist. We may recall that in Renaissance engineering art was the guiding discipline for engineering ana technology and the illustrated Notebooks of Agostino Ramelli, Jacob Leopold and the great Leonardoda Vinci testify to the symbiotic relationship between engineering design and art. Yet even then there was debate : a number of enthusiastic technologists of the Renaissance including Ramelli insisted that the mechanic arts had been perfected by the power of mathematics. As Alum Anderson said, "Just Occasionally, the past can be today in disguise." In passing, I may point out that while the use of Computers in engineering for applying numerical methods, mathematical analysis and modelling have been extensive, the future will see astonishing exploitation of the power of computers to extend our ability to visualise and gain for a feel for behavior : computers will permit a level of three dimensional and dynamic visualisation that will greatly enhance the engineers' design capabilities.

DESIGN IS CRUCIAL TO ENGINEERING :

Whatever I have said in the preceding section cannot deny science its due place in engineering and technology. There can be no question about the contribution science has made to technology during the 19th and 20th centuries - using methods as well as information from science; engineering disciplines have grown to have the ideal of scientific vigor and have become mirror images of the physical and chemical sciences. More importantly, new scientific discoveries have led to many new technologies and inventions and to innovations in old technologies and equipment. There are nevertheless some subtle differences between scientists and engineers. "Among the fundamental differences between scientists and engineers are their generally divergent objectives. The purest scientists observe and study the given world only to understand and explain it and its phenomena; the purest engineers want to manipulate the parts and processes of the given and found world into artefacts of benefit to mankind. Scientists analyse; engineers synthesize. The products of science thus to be words and theories; the products of engineering are plans and things". It would be obvious that in the spectrum between the pure scientists and the pure engineers are many who are both scientists and engineers irrespective of their original training and education. But the main point is that designing something, building and watching that something take shape and making it work is the essence of engineering. In fact, just as research is crucial to science, design is the cardinal factor in engineering and technology. A new technology implies a new process, a new plant or a new product and these have to be designed and engineered in other words, a strong design group and vibrant design activities are essential for engineering excellence just as frontier research activities are crucial for scientific excellence. One of the reasons for our country's failure to harness technologies has been the weakness in design activities. Whenever due importance had been given to design (even where initially we adopted known designs) there have been remarkable successes.

Paradigm shifts are needed periodically in any society, structure or organisation. The time has come for a shift back to the traditional engineering skills, to know how, to synthesis and integration and to a stress on complexity and uncertainty along with the nonverbal feel for physical behavior and common sense judgement.

IMPORTANCE OF DESIGN METHODOLOGY AND MATERIALS AND MANUFACTURING TECHNOLOGIES :

The importance of design has also

> **"Designing is the essence of engineering. If engineering education is to be distinctively different then the design content in the curricula should be substantial. In a developing country like India, where the industries do not yet have an R & D culture, the design content in our curricula should be quite substantial."**

been emphasised in the article by professor Srinath which I cited earlier. He has also beautifully brought our the importance of materials and manufacturing technologies and I quote : "Designing is the essence of engineering. If engineering education is to be distinctively different then the design content in the curricula, should be substantial. In USA, Canada and UK, the professional societies have prescribed a minimum design content, and if any programme fails to meet this minimum, accreditation is denied. In a developing country like India, where the industries do not yet have an R & D culture, the design content in our curricula should be quite substantial.

This design methodology should not be confused with the traditional courses in which problems have unique answer. Real design problems deal with open-end problems. From among a group of feasible solutions available to any particular problem, the ability to choose the right one which meets our constraints (materials availability, manufacturing capability, financial limitations, time frame, social expectations, cultural bounds, etc.,) is the hallmark of a well-trained engineer. Our engineering curricula and training programmes should aim at this. Without this, engineering education becomes meaningless . It is only when this ability coupled with creativity is inculcted in our students can the industries interact, develop and adopt newer technologies, and become competitive in international markets. While science definitely has a role to play in the engineering curricula, it cannot be at the expense of design training, Secondly, when one says that the products coming out of our industries need to compete with those coming from industrially advanced countries, one of the most basic factors on which this depends is our manufacturing engineering ability. Manufacturing engineering has become highly sophisticated and exposure to this subject has become absolutely essential. In today's context, design materials and manufacturing have become closely integrated, and a mastery of this alone can make our engineering industries internationally competitive. These three subject materials have to be carefully interwoven in our engineering curricula to give it a shape, form and strength." I have chosen verbatim quote from professor Srinath because I fully agree with his prescriptions and I have not come across a more precise and incisive analysis of the situation anywhere else. A friend of mine who read this lecture at manuscript stage commented. "All this is true for mechanical and production engineering but not for subjects like electronics." My answer to him was : "Please realise, we missed the electronics revolution and is reduced to depend on screw-driver technology because we did not develop the technology of electronic materials or of their processing."

CROSS-BREEDING AT THE POST GRADUATE LEVEL :

The B.E. / B. Tech. courses have been reduced in duration from five to four years after a higher secondary education of 12 years Simultaneously the M. E. / M. Tech. curriculum has been reduced from 4 semesters to 3 semesters or 1-1/2 years. These changes were implemented based on the recommendations made by the Mayudamma Committee. The four year B.E./B. Tech. curriculum has been working well and I have no specific comments on that. However, based on my experience of serving in committees that have conducted campus interviews and as an examiner for M. Tech thesis projects it is my opinion that the compression of M.E. / M. Tech course from four semesters to three semester has been a disaster. It has not helped in attracting better students to post graduate education nor is it producing adequately trained post-graduates in engineering. In many disciplines. M. Sc. degree holders in basic sciences (physics and chemistry) are admitted to an M. Tech. course. It is not possible to expose such candidates to the basic engineering courses, when the total duration of the course in only three semester. I strongly feel that the M. E. / M. Tech. curriculum in general should be increased to four semester and such a curriculum for M. Sc. degree on basic engineering subjects. Simultaneously for the B.E./B.Tech. students doing their M.E./ M.Tech. there can be pre-requisites of advanced courses in basic sciences and mathematics.

One of the drawbacks of the educational pattern in our country is that it is loaded against students who bloom late. For one thing we start our education at a very early age by pushing the students to the Nursery class when they are three and they finish their secondary school when they are fifteen and higher secondary school by the time they are seventeen. To a large extent the future and career of a young boy or a girl is decided by the academic achievements and abilities that he has acquired by the time he is 15 or 17, when he has to choose his further education and a career. It is a well accepted fact that different individuals develop their talents and abilities at different rates. As examples, Albert Einstein, Bukminister Fuller and Rabindranath Tagore were not considered as very bright students in their childhood. Fuller was even thrown out of Harvard University for poor Academic performance. All the three by later achievements are considered geniuses in their respective fields of Science, Engineering and Literature. It has been commented that, any one of them, if they were to appear in the entrance tests for admission to the prestigious institutions would have failed, for their

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genius did not find expression till much later in life. The post M.Sc. opportunity to do M. Tech. / M. E. courses has thus a merit in that it gives an opportunity for some of the late blossoming students to become engineers. It is also a very useful way of crossbreeding between disciplines. However, I feel that a more useful programme would be an integrated M. E. courses of four year's duration for science graduates. This has been introduced at the Indian Institute of Science and it will be a good idea to start a few similar M.E. / M. Tech courses in two or three more Institutions.

TINKERING CULTURE :

Let us not forget that a technological society is synonymous with a thinking culture, where every individual has basic technical skills and can take care of simple things like replacing a fuse, fixing a leaking tap, changing a tyre in a car, repairing a bicycle, changing the gasket in a pressure cooker etc., The absence of tinkering culture in India is conspicuous; in the west, tools of a tinkerer (most basic are screwdrivers, hammers, spanners, saws, drills, soldering irons etc.) are household items and every child grows up with these around him and start using them to dismantle toys as well as to re-assemble them. A tinkering child will watch adults at repair work and later demand to do the work himself /herself. "R & D can emerge only out of competitive tinkering. Without a tinkering culture, there is no innovation and a nation is doomed to depend on imported technology."

CONCLUSION :

There is trend, again not unique to our country, but universal. That many engineers ultimately end up in profession that have no relevance to their training and education. Today, sales, marketing, finance, real estate, software and services sector offer jobs that are more remunerative and apparently more glamorous than hardware, manufacturing and production. The brain-drain to the Gulf and West continues. In this context, the following extract from Radhakrishnan Committee's report on University Education is relevant....... "while professional men in a large degree are in key positions in modern society, professional education has failed in one of its large responsibilities, that of developing principles and philosophy by which professional men should live and work. To the extent that such purpose and philosophy are lacking, the engineer may be at service of any one who will pay him well regardless of the social worth of his services, the lawyer's skill may be for sale for right or wrong, and the physician may seek the place of largest income, rather than that of greatest service. While each may have high skill, the total effect may be great internal stress and social deterioration." I feel that teachers have a responsibility for developing in the students a sensitivity about their duty to the country and a pride in their profession. This alone will ensure that an engineer will not seek employment in other sectors or countries just because he is paid well.

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