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HIGHER TECHNICAL EDUCATION IN INDIA – PROFILE OF GROWTH AND FUTURE PERSPECTIVES

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1.0 Historical Backdrop

The world's largest democracy, India, has shown a tremendous growth of its techno-economic prowess, over the last 62 years of post-independence era, sustaining an economic growth of 7 to 8% during the last 10 years, attaining self-reliance in strategic sectors and in key areas including food security, making Indian economy the third largest economies of the world and above all making India proud by meeting the requirement of S&T manpower of the advanced nation's of the world for their outsourced qualified and skilled brainpower to manage the businesses, knowledge industries and research centres, both in India and abroad. All this could be possible primarily because of a formidable support offered by India's ever growing technical education sector. Just think of India adding to it's existing strength of technical education, 08 new IITs, 07 IIMs, 15 Central Universities, 10 NITs, 05 IIScs and 20 IIITs during 2008, the year of global recession. It goes to acknowledge that India is and will continue to be one of the major contributory to the growth of S&T manpower to man industries and enterprises at home and abroad, creating and providing the necessary support for the growth of knowledge and innovation power to foster new businesses and enterprises in the knowledge age, challenging the era of economic slowdown and equipping the world at large with the wings of knowledge and with the propulsive force of techno-economic power to take newer flights of success thus providing a major upturn to the economic slowdown and creating a brighter and better tomorrow for people around the world. This is the context in which we have to view India's technical education today and it's perspective for growth for tomorrow. This is well perceived in the words of the architect of the blue print for the Knowledge Society in India, A.P.J. Abdul Kalam:

"Imagine a workforce able to meet the entire world's shortage of technical and professional graduates. Imagine companies and universities from around the world gravitating to India as the premier scientific and technological research and development environment. Imagine an India in which cities are far cleaner and more modern, citizens more enlightened and responsible, entrepreneurs more dynamic and sophisticated, institutions far more effective and responsive."

INDIA: VISION 2020
Towards a Knowledge Society

The National Knowledge Commission NKC of India in it's report to the nation 2007 and 2008 has recommended establishment of 1500 new Universities to meet India's higher education growth plans to meet the requirement of manpower of both the Indian industries and the foreign companies outsourcing their manpower and services from India. The NKC has also suggested a number of well intentioned reforms to strengthen the creation of the talented and skill pool and also to improve the regulatory mechanism of the higher and technical education. [2]

Looking at the historical backdrop of India's Science and Technological Education, one cannot stop from taking note of immense science and technology capabilities of ancient India as is evident from the narrations of highly sophisticated and advanced warfare in the Ramayana and in the Mahabharata, the two highly celebrated and historically mind-boggling classics of India. Capabilities like creating Rama Setu penetrating deep into the sea, connecting Dhanushkoti at India's sea cost to Sri Lanka, floating of stones on the sea surface, guided missiles fired by Ravana and equally matched by the firepower of the highly sophisticated warfare launched by Rama including the Brahmastra, capable of devastating a major portion of the universe, Sita, the daughter of king Janak taking birth from an earthen pot buried in the open crop field, sounding like a test tube baby of the modern times, five sons of Kunti in the Mahabharta taking birth as tailor made human beings, equally matched by 100 Kaurva sons of Gandhari are the glimpses of a highly advanced and sophisticated biotech development of the Ramayana and Mahabharta period. The classics of India namely, Vedas and Upnishads speak of a profound understanding of the creation and provide a sound basis for of understanding of the scientific principles of sustenance of life on planet earth. The ancient science and technology education in India laid a solid foundation for the growth of a materially advanced, spiritually and ethically highly advanced Indian society, described as the wonder that was India by Learned Scholars on ancient India.

The systems of town planning in ancient India discovered in Harappa and Mohen-jo-daro and several other sites including in Central India, near Vidisha in Madhya Pradesh, the techniques of purifying metals such as Iron, Copper, Zinc, Nickel and creating alloys such as Bronze and Brass mixing of metals and making composites as is evident from the ancient idols and jewellery of ancient India are sufficient to provide the glimpses of the science and technology tampered minds of ancient Indians. The Iron pillar in the close vicinity of Qutub Minar of Delhi, the discovered sophisticated designs and navigation systems of ships and vessels which sailed far and wide up to Mayan civilization from the well-developed shipyards of Lothal in Gujarat further strengthen the view that yesterday's India was a sound economic power thriving on Science and Technology capabilities of it's people. The excellence of manufactured articles in ancient and medieval India, e.g., fabrics of cotton and silk, embroideries, painted and enamelled wares, steel guns, swords, knives and scissors, gold and silver ornaments, Indian inks, paints, colours and handmade paper, paintings on stone with natural colours surviving several centuries, fine carvings on rocks often from top to bottom i.e. from the head shikhara to the foundation of a temple as in Ajanta and Ellora are to date a major attraction for the scientific community interested in decoding the S&T strength of ancient India. This excellence was achieved and maintained for centuries with dependable technical education practices handed down from generations to generations through hereditary learning, pupilage training and in the training schools attached to workshops.

The ancient tradition of integrating science, technology and spirituality continued to the Buddhist period wherein we find the ancient Indian Universities such as Nalanda (in Bihar State) and Takshila (now in Pakistan) attracting scholars from around the world for the quest of knowledge and scholarship. It is not the intention of the present study to go deep into India's science and technology antiquity but to provide a feel of the thrill, excitement and love for science and technology in ancient India which through genetic transcription continued to create an upsurge for science and technology education in India in the post-independent era. This thrill and excitement continues to date and is an inspiration for millions of young Indians who turn towards science and technology education in India in great numbers to institutions of higher learning in technical education.

Looking at the modern era of science and technology education, it all began in 1794 when the then British Government in India set up a school of surveying in Madras, originally restricted to the British students as surveying was to generate maps and surveys to support British army to conquer Indian territories. As British moved to north, a school of surveying was also established in 1806 at Saharanpur which later became Thompson College of Engineering in 1847, at Roorkee, becoming University of Roorkee in 1947 and more recently IIT Roorkee in 1997. The early development of Collegiate Technical Education witnessed the establishment of Bengal Engineering College, Sivpur in 1856, Guindy College of Engineering, Madras in 1859, Tata Institute, now known as Indian Institute of Science in 1909, Delhi Polytechnic now known as Delhi College of Engineering in 1941, Jabalpur Engineering College in 1947. The 13 Regional Engineering Colleges and the 5 IITs were later added in the late 50's and early 60's to strengthen India's higher technical education. This was further supported by the establishment of 4 TTTIs for technical teachers training and a chain of research laboratories for scientific and technological advancement supported by DRDO, CSIR, Department of Atomic Energy, Department of Agriculture and Department of Science and Technology together paving the way for India's self-reliance in science and technology in strategic and key areas. Phenomenal growth of technical education has however, been witnessed in the post liberalisation era which began from 1991 onwards with an upsurge of private initiatives in technical education. Table 1 gives the growth profile of technical education in India prior to the liberalisation era and Table 2 depicts the growth of technical education in the post-liberalisation era.

2.0 Present Status of Technical Education in India - Profile of Growth of UG / PG and Doctoral Programs.

2.1 <u>UG Technical Education</u>

Under Graduate Technical education in India expanded rapidly soon after independence, as is clear from Table 1. From 50 institutions with a total intake of 3700 in 1950, India had sevenfold increase in number of institutions and 18 times increase in forty years, in 1990. Thereafter, the advent of liberalisation and privatisation of the economy provided increased growth for nation's economy and thus prompted private initiative to accelerate the pace of engineering education in India. In the post-liberalised era, the number of institutions went up to 1668 i.e. fivefold increase beyond 1990 in just 17 years, likewise the intake to undergraduate programs also increased from 66600 to 653290 i.e. approximately 10 times. Naturally, India became one of the major players in producing technically qualified under graduate man power. Much of this rapid expansion of technical education was prompted by the increased need of manpower for the IT and IT related industries in India as also to meet the outsourced requirement of the IT industries and businesses in the advanced countries, especially US. The growth pattern of technical education still continues despite the global slowdown of financial sector. As is evident from the AICTE receiving 886 applications for establishment of new institutions in various States of India for 2009-10. This may further add UG intake of about 3 lakhs, if all the applications for new institutions are allowed, thus taking the under graduate intake to a staggering high at around 10 lakhs i.e. 1 million.

Table 1: Growth of Degree Level Engineering Institutions (1947 to 1990)

Year	No. Of Institutions	Students Intake	Intake per Institution (Average)
1950	50	3700	74
1960	110	16000	145
1970	145	18200	125
1980	158	28500	180
1990	337	66600	198

Source: AICTE Annual Reports and Technical Education in Independent India, 1947-1997

Table 2: Growth of Degree Level Engineering Institutions (post-liberalisation era 1991 onwards)

Year	No. of Institutions	Students Intake	Intake per Institution (Average)
1990	337	66600	198
2000	776	185758	240
2003	1208	359721	298
2004	1265	404800	320
2005	1346	452260	336
2006	1511	550986	364
2007	1668	653290	392

The Regional unbalance continues to be a major issue despite expansion of technical education opportunities in states in northern India. Two-third of India's technical education at UG level is still in the states of Tamil Nadu, Karnataka, Andhra and Maharashtra, as is clear from Table 3 below which gives the regional distribution of sanctioned intake for UG and PG programs in engineering as per AICTE report 2007.

Table 3: Regional Distribution of Sanctioned Intake for UG and PG Programs in Engineering

Regions (as per AICTE groupings)	Under Graduate Programs in Engineering as on 31.08.2007		Post-Graduate Programs in Engineering as in Session 2007-08	
	Number of Institutions	Sanctioned Intake Capacity	Number of Institutions	Sanctioned Intake capacity
Central (MP, Chattisgarh, Gujarat)	166	66161 (10.13%)	46	4334 (12.02%)
Eastern (Mizoram, Sikkim, Orissa, WB, Tripura, Meghalaya, Arunachal Pradesh, A&N, Assam, Manipur, Nagaland, Jharkh.)	128	40613 (06.22%)	37	2686 (07.45%)
Northern (Bihar, UP, Utaranchal)	155	57988 (08.88%)	34	2100 (05.83%)
NorthWest (Chandigarh, Haryana, J&K, Delhi, Punjab, Rajasthan, Himachal Pr.)	206	73251 (11.21%)	50	4563 (12.66%)
Southern (Andhra Pradesh, Pondicherry, Tamilnadu)	593	256571 (39.26%)	193	14081 (39.06%)
South-West (Karnataka, Kerala)	234	91939 (14.07%)	56	4545 (12.61%)
Western (Maharashtra, Goa, Daman & Diu, Dadar NH)	186	66767 (10.22%)	67	3743 (10.38%)
INDIA	1668	653290 (100. %)	483	36052 (100. %)

Looking at the availability of seats at UG and PG level per lakh (10^5) of population in India, it may be noted from Table 4 further depicts the regional imbalance. The State of Tamil Nadu has the highest sanctioned intake of 189 per lakh of its population, State of Andhra Pradesh 161, Karnataka 110, Kerala 89 and Maharashtra 62, while the large States like Uttar Pradesh and Madhya Pradesh have28 and 62 seats intake in Engineering per lac population (See Table 4).

Table 4: State wise Sanctioned Seats per Lakh of Population in Degree & PG level courses in Engineering

Sl. No.	States/UTs	Projected Population, 2006 (In Lakh)	Degree Level As on 31.08.2007		Post Graduate Level as in 2007-08 Session		No. Per one Lakh Population UG+PG
			San-ctioned Intake	No. Per lakh of popu-lation	San-ctioned Intake	No. Per lakh of Popu-lation	
1	Nagaland	21.19	0	0	0	0	0
2	Mizoram	9.46	0	0	0	0	0
3	Bihar	907.52	1690	1.86	180	0.2	2.06
4	Assam	286.65	870	3.03	156	0.54	3.57
5	Manipur	23.08	115	4.98	0	0	4.98
6	Meghalaya	24.70	240	9.71	0	0	9.71
7	Jammu & Kashmir	109.41	1401	12.81	36	0.33	13.34
8	Tripura	34.07	490	14.37	0	0	14.37
9	Jharkhand	292.99	3438	11.73	888	3.03	14.76
10	West Bengal	852.16	16968	19.91	1318	1.55	21.46
11	Arunachal Pradesh	11.69	210	17.96	54	4.62	22.58
12	Uttar Pradesh	1,832.82	51775	28.25	1669	0.91	29.16
13	Himachal Pradesh	64.55	1807	27.99	162	2.51	30.50
14	Chattisgarh	225.94	7006	31.01	356	1.58	32.59
15	Gujarat	549.79	17408	31.66	1515	2.75	34.41
16	Rajasthan	622.76	20683	33.21	804	1.29	34.50
17	Orissa	388.87	17817	45.82	270	0.69	46.51
18	Delhi	160.21	6943	43.34	818	5.11	48.45
19	Uttranchal	92.19	4523	49.06	251	2.72	51.78
20	Goa	14.92	809	54.22	69	4.62	58.84
	INDIA	11121.86	653290	58.74	36052	3.42	62.16
21	Maharashtra	1,048.04	65958	62.93	3674	3.50	66.43
22	Madya Pradesh	663.90	41747	62.88	2463	3.70	66.58
23	Haryana	233.14	22750	68.51	1125	4.83	73.34
24	Punjab	260.59	18879	72.45	1325	5.08	77.53
25	Sikkim	5.76	465	80.73	0	0	80.73
26	Kerala	332.65	29790	89.55	1061	3.19	92.74
27	Karnataka	562.58	62149	110.47	3484	6.19	116.66
28	Other UTs (Chandigarh, Pondicherry)	31.76	3458 (788+ 2670)	108.88	556 (293+ 263)	17.51	126.39
29	Andhra Pradesh	807.12	130669	161.90	6693	8.29	170.19
30	Tamil Nadu	651.35	123232	189.19	7125	10.94	200.13

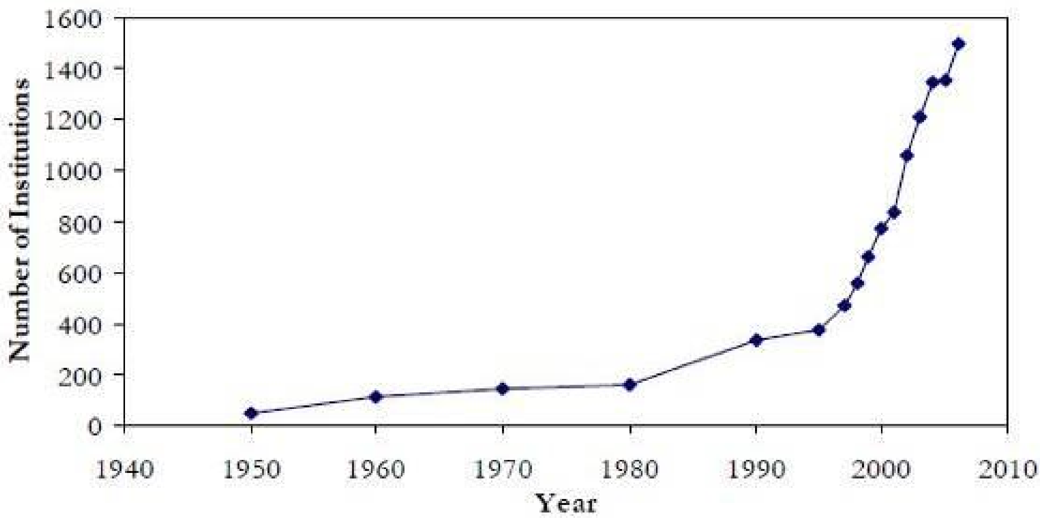


Figure 1: Growth of Degree Institutions 1950-2007 (updated from Banerjee and Muley, 2008)

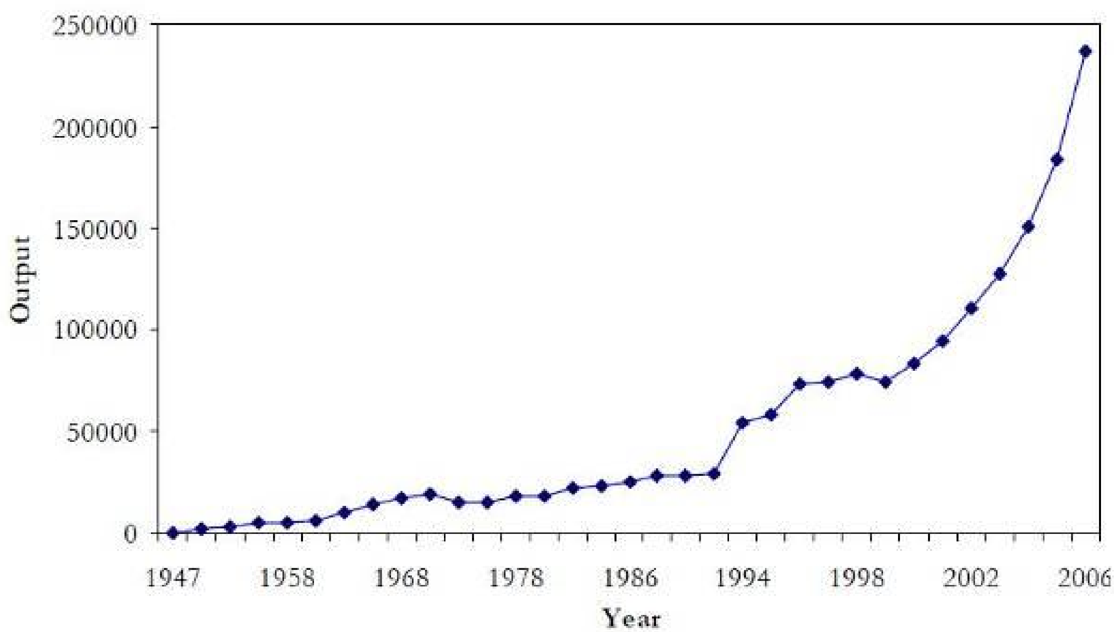


Figure 2: Growth of Sanctioned Intake of Graduates 1947-2007 (4)

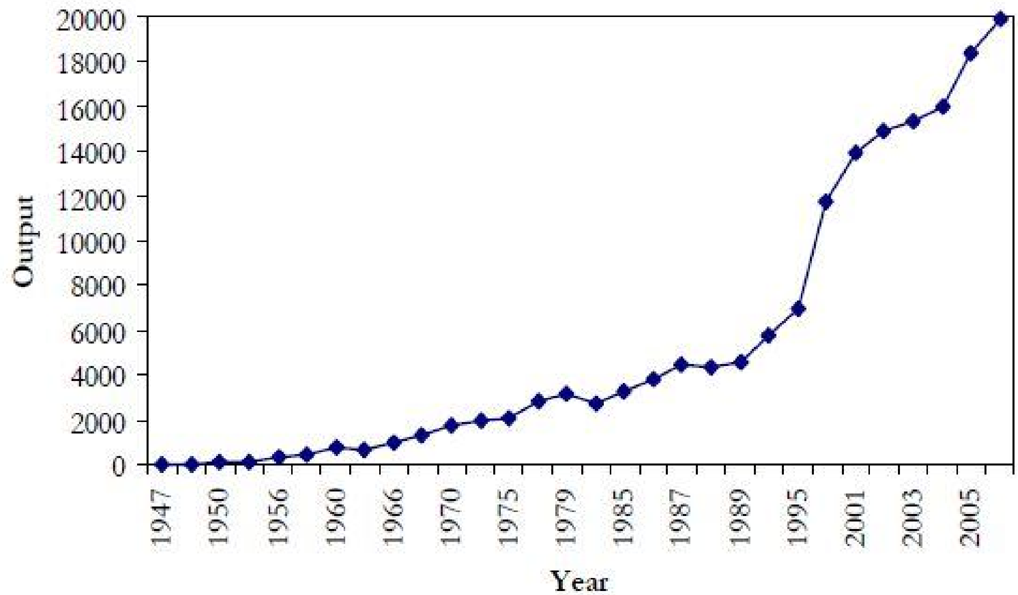


Figure 3: Total Output of Engineering Graduates 1947-2007 (updated from Banerjee and Muley, 2008)

It may be seen that the post-liberalisation era which began in July 1991 has attracted a large private initiative in Technical Education providing for tenfold growth in student intake at UG levels in Engineering from 66,600 in 1992 to 6,53,290 in 2007. Almost 100,000 seats have further been added since 2007 taking total enrolment in engineering degree level programs to over 7.5 lakhs. The irony however, is that commensurate with this tenfold increase in intake and phenomenal growth in number of engineering institutions, the development of quality faculty and necessary academic infrastructure has not been taken proper care of resulting into uncontrolled growth of quantity without assured quality and industry relevance. It is also pertinent to note that despite phenomenal growth of intake and number of engineering institutions, India still is far behind in terms of the availability of engineering admission opportunities per million population as compared to other advanced nations of the world, as may be seen from Figures: 4 – 6. A study carried out by Banerjee and Muley [4] has further revealed a relationship between the number of engineering graduates with the population and the GDP. A plot of the number of engineering graduates (E) per million population to the real GDP per capita is shown in figure 7 and reveals a linear trend. The best fit equation obtained is:

$$E/Pop = A + B\ GDP/Population$$

where A= -51.034 and B= 0.081

Figure 4: Engineering Bachelor's Degrees per Million Population for US [4]

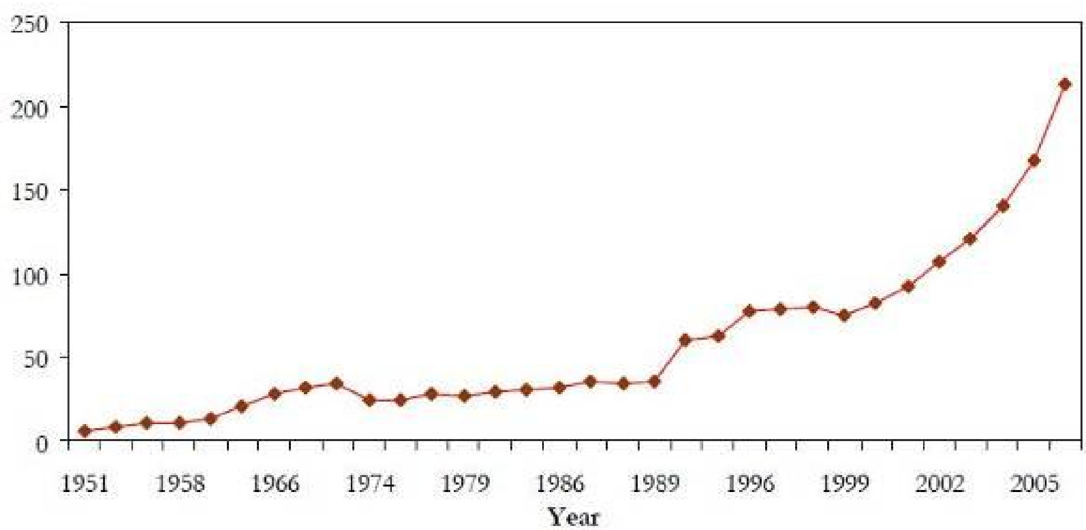


Figure 5: Growth of engineering graduates per million population in India since independence (4)

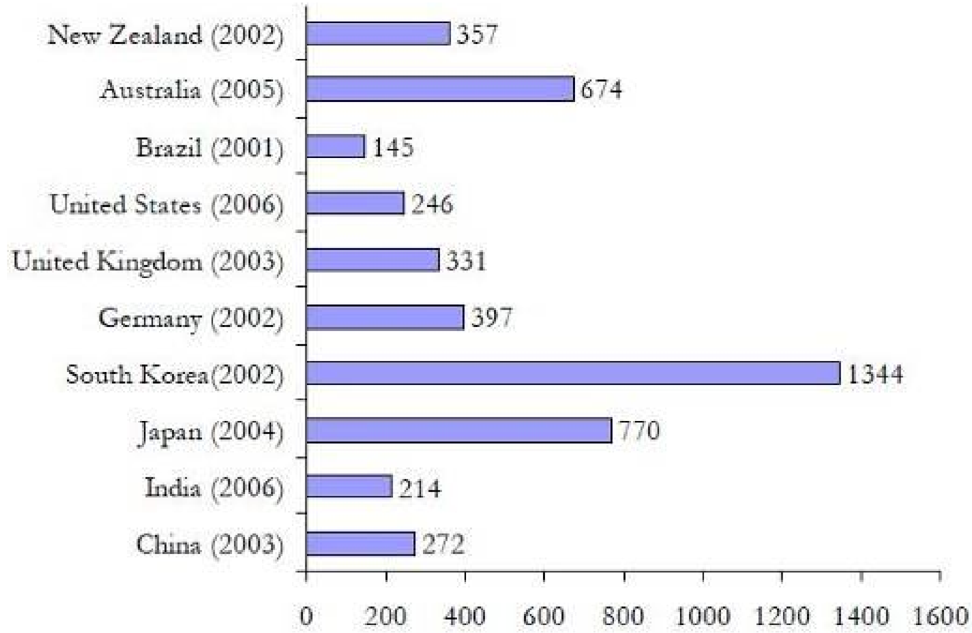


Figure 6: Engineers per million population for different countries [4]

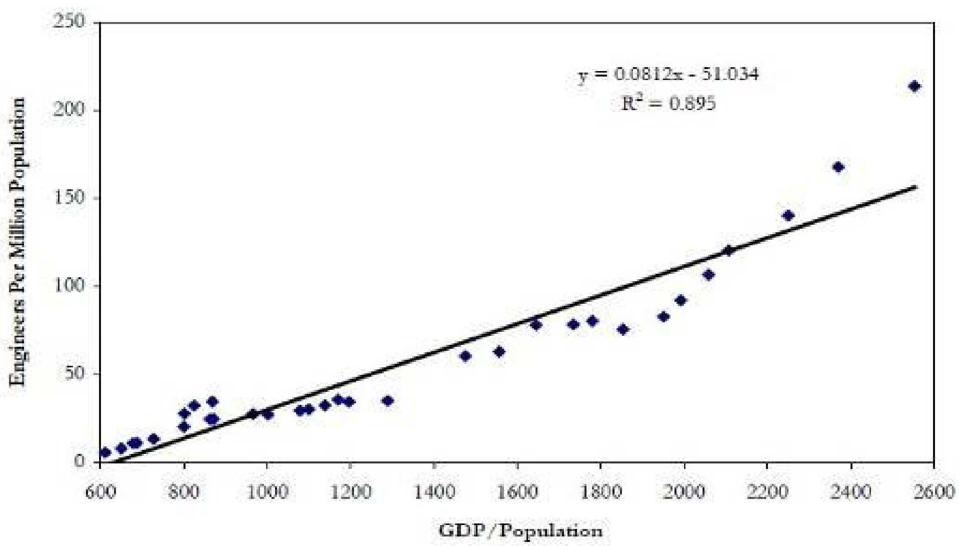


Figure 7: Engineers per million population to Real GDP per capita (4)

2.2 Postgraduate Programs and Doctoral Research.

2.2.1 Postgraduate Output in Engineering and Technology.

The rapid pace with which the number of institutions and enrolment in engineering degree program has grown required a rapid development of postgraduate degree programme in India to provide specialized skilled manpower to meet the requirement of the faculty for engineering institutions, industries and R&D Centers. However, this has not kept its pace. Indian technical education growth plan being under-graduate centric it could not promote PG and research programs due to shortage of well qualified faculty in the privately owned institutions partnership. The commonly offered post-graduate programs in India in engineering relate to the grant of Master of Technology (M. Tech) or Master of Engineering (M.E) degrees, both being equivalent. These courses are of two-year duration and involve a major project leading to a dissertation, a master's level thesis.

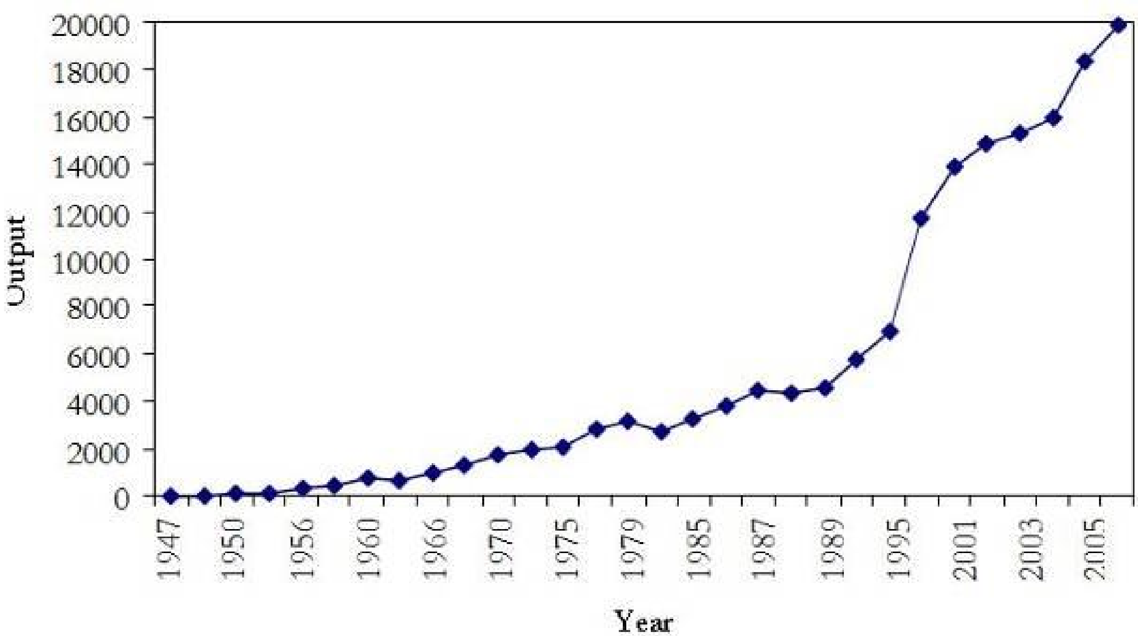


Figure 8: Masters Output from 1947-2006 (4)

It may be seen that the Master's program level output in India in engineering in 2005 was around 20000 as against under-graduate, Bachelor's output in engineering of 245000. The Master's output in engineering thus, amounts to approximately 8%. The situation has not changed much as far as the percentage of PG with respect to UG is concerned. This is a matter of great concern as the rise of India as the third largest economic power required a focus on growth of knowledge and technology power which necessitates a much higher contribution to the post graduate and doctoral output. Compared to this, in US the post graduate population in engineering amounted to approximately 50% of under graduate population as per Engineering Trends 2009. This is where India differs significantly to US in its approach to manpower development in Engineering and Technology. Now that the Indian economy has grown to the level of being the third largest economy of the world and that the advance nations are looking at India for outsourcing their highly skilled and knowledge manpower for its industries and R&D centres, it is imperative for India to significantly enhance its post graduate and research manpower output. The initiative taken in this regard by the Ministry of HRD of Govt. Of India to enhance opportunities for Post Graduate education in the self-financing institution must however, be implemented with utmost caution so that it may not end-up with low quality post graduate education as has happened in the case of great many under graduate institutions under self-financing category. The focus on quality faculty requires increased investment on developing faculty competence. India has to devise suitable strategies to combat the problem of faculty shortage to strengthen its technical education. Further, the new knowledge age requires a shift from academic infrastructure to world class knowledge infrastructure. This will help integrate advantage technology in technical education and will promote knowledge sharing and knowledge and innovation management. A tech-savvy student and faculty community should form the backbone of tomorrow's technical education in India. It would also be necessary to create an academic environment in which the power of science and the might of technology is nurtured together in a seamless environment of science and engineering. The future growth of technical education specially post-graduate and research education in India has to pay a greater attention to this aspect of creating synergy between education and research and more so the synergy between science and engineering.

2.2.2 Doctorates in Engineering and Technology.

The Banerjee and Muley report [4] has brought out the trend of engineering PhD Degrees awarded each year from 1954-2005. It indicates that the overall growth rate during 1954-2005 has been at 8% per year, see Fig. 9. Currently, the PhDs awarded in engineering amount to almost 1% of the enrolments in engineering degree program.

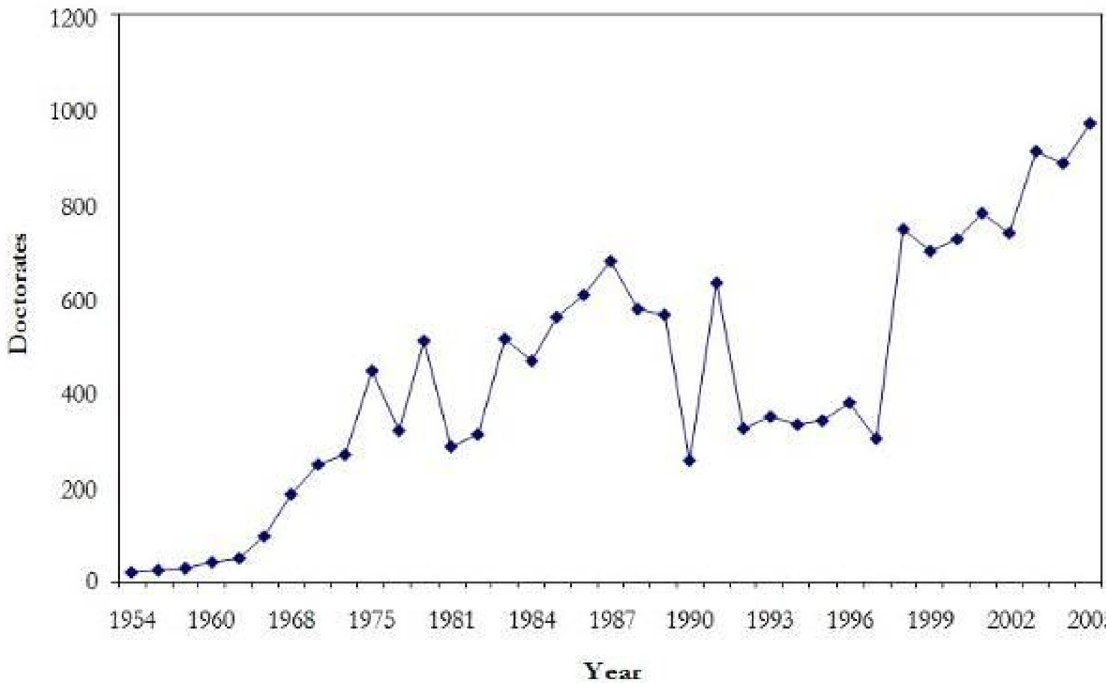


Figure 9: Engineering Doctorate Degrees Awarded in India (4)

Compared to this, the engineering trends in US indicate that the Master's and Doctorate degree programs in engineering have grown to 52% and 12.3% of the degrees awarded at UG Bachelor's levels as per engineering trends 2009. Further details of the US trends are given in Figs.: 10–12 (Source: http://www.engtrends.com/degrees1945-003.php). The US trends also indicate a rising trend for the Engineering Doctorate programs while the Master's and Bachelor's program are nearly stagnant. India requires corrective measures to correct its present trends of engineering education so as to sustain its march in the knowledge society. The Doctoral level research has to necessarily increasingly lean towards industry relevance to ensure its benefits for technology up gradation and product innovation to the industries in the new knowledge age. Increased partnership with the industry for Doctoral research, industry sponsored R&D and collaborative research between Universities even across the boundaries of the nation's are the new imperatives for sustaining industry relevance in Doctoral research and R&D

program. India has tremendous opportunities for such collaborative research programs with advanced nation's across the world with whom it trades and transacts its manpower, goods and services.

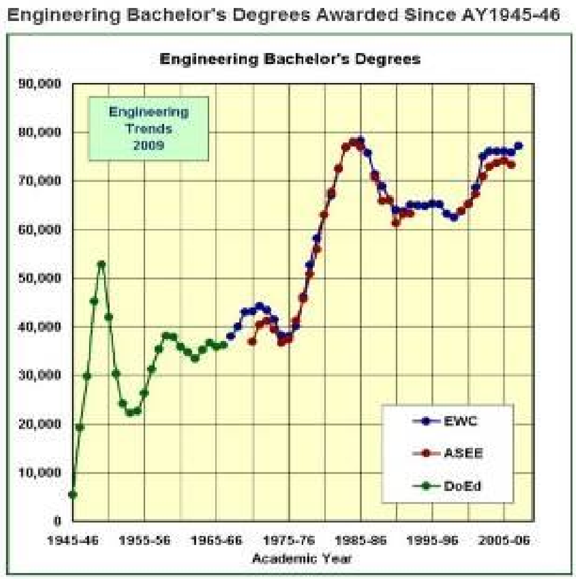


Figure 10: Trend of Bachelors degree in engineering

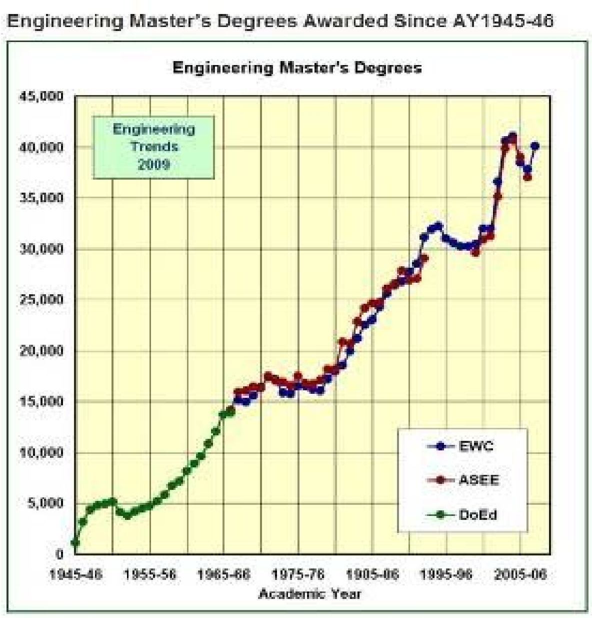
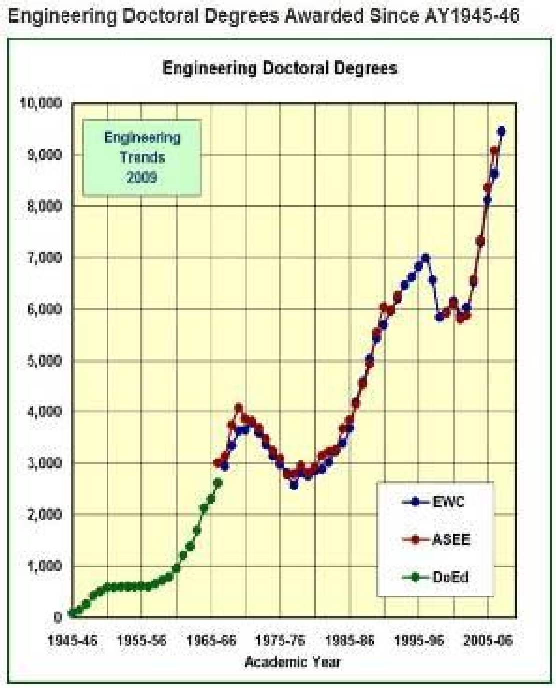


Figure 11: Trend of Masters degree in engineering in U.S.



Source: http://www.engtrends.com/degrees1945-003.php

Figure 12: Trend of Doctoral degree in engineering in U.S. since 1945.

3.0 Role of Private and Foreign institutions.

The private partnership in technical education in India, though made its beginning at the start of the 20th century with the establishment of the Tata Institute of Science at Bangalore in 1906 and later Birla Institute of technology and science, BITS Ranchi (1955) and BIT Pilani (1964), the rapid expansion of self-financed institutions of engineering and technology managed by societies and trusts took place soon after the advent of liberalisation of Indian economy in 1991. There were 510 private institutions as against 159 in 1999-2000, accounting for approximately 77% of total intake at UG level in India. The share of the government funded institutions was 23%. The scenario has further changed to 85% intake at UG level under self-financing private institutions, reducing the government institution share to 15% in 2003-04 as per Natarajan (2004). The situation has further changed to over 90% intake in UG programs in India, in its nearly 2000 colleges of engineering currently being enrolled into privately managed self-financing institutions. The private participation in technical education has thus, grown to an enormous size reducing government commitment to undergraduate program to around 10%. This while on one hand relieved the government from expenditure on under graduate manpower development in engineering and technology has prompted mushrooming of private institutions often not well-equipped with the necessary academic infrastructure and also lacking in qualified faculty. This has created UG centric growth of technical education in India.

The fallout has been that the technical education has become a major education industry and also a business for private societies and trusts. The focus on quality has taken a back seat to multiplying intake and number of institutions as being the priority to enhance inflow of revenue from the fees charged from the students. Ideally, the private participation should have enhanced philanthropic contributions coming from corporates, industry and society to technical education. This has not happened. Further, the major corporate houses, large industries, PSUs and multinational industries have not come forward to join the private initiative for supporting the growth of quality technical education in India. This is a major area of concern and requires strategic interventions on behalf of the government policy.

Table 5 gives below the growth of engineering institutions in India at UG level indicating the share of private and government institutions.

Table 5: Growth of Engineering Institutions in India at the Undergraduate Level in the post-liberalisation era.

Year	No. Of Institutions (%)			Intake (%)		
	Pvt.	**Govt.**	**Total**	**Pvt.**	**Govt.**	**Total**
1999-2000	510	159	669	133811	40307	174118
	(76%)	(24%)	(100%)	(77%)	(23%)	(100%)
2000-2001	667 80%	171 20%	838 100%	174118 80%	55406 20%	232229 100%
2001-2002	868	189	1057	243978	51818	295796
	82%	18%	100%	82%	18%	100%
2002-2003	1017	191	1028	305327	54394	359721
	84%	16%	100%	84%	16%	100%
2003-2004	1071	194	1265	325747	55056	380803
	85%	15%	100%	85%	15%	100%

Source: *Natarajan, R. Role of Privatization in professional education. In: Powar, K.B. & Johar, K.L. (Eds.), Private Initiatives in Higher Education, Sneh Prakashan, New Delhi, 2004.*

4.0 Regulatory Mechanism

India's higher education is regulated by the University Grants Commission as far as the University education is concerned and by All India Council of Technical Education, AICTE. The AICTE was created as an apex statutory body in 1986 for proper planning & co-ordinated development of technical education system throughout the country. It has its headquarters in Delhi and regional offices located at Chandigarh, Bombay, Bhopal, Chennai, Kolkata and Hyderabad. The AICTE has four boards of UG studies, PG studies, Management studies and Technician education. In addition it has bureaus to co-ordinate planning and development of quality technical education. These relate to bureaus of Administration and Finance, Planning and Coordination, Bureau of Under Graduate Studies, Bureau of Post Graduate Education and Research, Bureau of Faculty Development, Bureau of Research and Institutional Development and Bureau of Quality Assurance. The AICTE is responsible for approval of new engineering institutions, increase in intake in the existing programs, addition of new courses, formulation of norms and standards and their compliance, developing regulatory mechanism for collaboration with foreign universities and providing support for the growth of industry academia alliances, modernisation of academic infrastructure, faculty development and capacity building through short term courses, seminars, conferences and support for foreign visits of the faculty of the AICTE approved institutions. The plan budget of AICTE for 2006-07 stood at Rs. 255.034 crores while the non-plan stood at Rs. 283.92 crores. Several innovative schemes to promote faculty quality offered by AICTE have been initiated during the last 20 years. These include Quality Improvement Program (QIP) for teachers of Degree and Polytechnics, career awards for young teachers, Emeritus Fellowship to the super-annuated faculty and national Doctoral Fellowship to attract young talented research scholars into institutions of higher standing such as the IITs, IISc etc. As per the Annual Report of AICTE 2006-07 a total of 25 career award for young teachers have been awarded by the AICTE which is unfortunately a very small contribution to the body of approximately 80000 teaching community in engineering institutions around the country. Likewise, the support for emeritus fellowship which began in 1994-95 has grown to 14 emeritus fellowships with a total grant of 42 lakhs in 2006-07 as per the AICTE Report. The payment of Rs. 3 lakhs for career award for a young teacher and a similar amount for emeritus fellowship is not really adequate to justify the objective of the scheme i.e. to attract meritorious faculty to engage into quality research and academic excellence in case of young teacher's career award and attracting meritorious retired faculty to the emeritus fellowship in institutions of engineering. This is a grey area in which AICTE could invest much more and support capacity building in teaching and research. The bulk of the AICTE expenditure amounting to Rs. 221.82 crores went as grant to NITs in the country, as per the AICTE report of 2006-07.

One of the major weaknesses of the AICTE has been that it has not been able to put brakes on uncontrolled expansion of technical education nor could ensure strict compliance of its norms and standards. The mushrooming of engineering institutions at Degree level in India has created a chaotic situation in which admissions to engineering are being made merely on pass percentage at Senior Secondary level or with almost zero marks in the entrance test for admission. This has resulted into utterly poor quality of intake in great many institutions. Further, the lack of well trained and qualified faculty and the lust of the private management to multiply intake and number of institutions under its control rather than focussing on building islands and clusters of quality education has eroded India's technical education to the extent that the industry associations such as NASSCOM, CII, FICCI and others have gone to the extent of saying that not more than 25% of the graduates from engineering institutions in India are employable in the industry. Apparently this has resulted into under-employment of engineering graduates.

An area of importance from the point of view of improving output of engineering institutions in India and striking their compatibility and acceptance with the quality of manpower produced in the advanced nations of the world is to strengthen India's accreditation system. Currently, India has NAAC (National Assessment and Accreditation Council) for the Universities under University Grants Commission, UGC of India and NBA (National Board of Accreditation) under AICTE for Engineering and Technology institutions. Both the NAAC and the NBA require significant improvement in its approach as well as its methodology for assessing the academic programs and institutions as per the accreditation systems followed in US, Canada and UK. This exercise is currently taking place at NBA level for engineering institutions. This will enable India to comply with the WTO requirement for movement of qualified workforce across the boundaries of the nations. The current status of accredited engineering institutions in India is given in Table 6. The total number of accredited institutions adds up to 638 out of approximately 2000 colleges of engineering in India.

Table 6: Status of accreditation of institutions in various states of India.

Sl. No.	State	Number of Accredited Institutions	Sl. No.	State	Number of Accredited Institutions
1.	Tamil Nadu	138	**12.**	Haryana	22
2.	Karnataka	67	**13.**	HP	1
3.	Andhra Pradesh	68	**14.**	J&K	3
4.	Kerala	16	**15.**	Goa	3
5.	Maharashtra	104	**16.**	Arunachal	1
6.	UP	65	**17.**	Assam	1
7.	MP	31	**18.**	Chhatisgarh	5
8.	WB	36	**19.**	Delhi	13
9.	Orissa	23	**20.**	Rajasthan	8
10.	Uttaranchal	5	**21.**	Punjab	9
11.	Gujarat	22	**22.**	Pondicherry	5
			23.	Sikkim	1

5.0 Government Support and National Policies

The government support to technical education in India has been restricted to the plan and non-plan budgetary support to the government institutions, regional engineering colleges (now the NITs), IITs and to TTTIs (now NITTRs). A limited budget was also made available by AICTE for enhancing industry academia interface, faculty development and for thrust area research programs. The AICTE also funded master's scholarships for those taking admissions in the master's program through valid GATE scores in the AICTE approved institutions. More recently, the Government of India has taken initiative to increase intake in the IITs, NITs and institutions under Government control to accommodate its obligation for admission to the other backward caste (27% of the total intake). This has undoubtedly increased the budgetary spending on higher education in the IITs and in the NITs and the support of the Central Government to the State for Technical Education.

Table 7 gives budget expenditure on technical education by government of India as per the report on Funding of Higher Education by Mungekar Committee (2005) [5]. It may be seen that the bulk of the expenditure on technical education is for the IITs, IIMs and RECs (now NITs), while only 22% is allocated to others sectors including the funding to various States for their technical institutions. Further, the expenditure on higher education has been in the range of 0.35 to 0.47% of GNP of which Technical Education accounts for 0.13 to 0.15 % of GNP, while, in many advanced nations, this expenditure is upto 4%-6% of GDP. (See Table 9).

Table 7
Budget Expenditure on Technical Education in India
(Rs in Crores)

Year	In Current Prices			In 1993-94 Prices		
	Plan	Non Plan	Total	Plan	Non Plan	Total
1990-91	265.38	487.63	753.01	360.41	662.24	1022.65
1991-92	289.99	519.47	809.46	346.15	620.07	966.22
1992-93	313.87	593.25	907.12	344.61	651.36	995.97
1993-94	345.48	672.25	1017.73	345.48	672.25	1017.73
1994-95	471.40	717.86	1189.26	430.12	655.00	1085.12
1995-96	488.85	801.40	1290.25	409.01	670.51	1079.51
1996-97	554.05	895.96	1450.01	431.98	698.55	1130.53
1997-98	619.37	1003.19	1622.56	452.49	732.90	1185.39
1998-99	706.33	1366.81	2073.14	477.73	924.45	1402.17
1999-2000	874.18	1584.78	2458.96	569.23	1031.94	1601.17
2000-01	735.21	1792.81	2528.02	462.78	1128.48	1591.25
2001-02	789.35	1771.04	2560.39	480.52	1078.13	1558.66
2002-03RE	832.14	2056.36	2888.50	486.45	1202.11	1688.57
2003-04BE	1076.58	2105.73	3182.31	611.17	1195.41	1806.58

Source: *Analysis of Budget Expenditure on Education* (various years)

Table 8: Union Government's Expenditure on Technical Education [5].

Union Government's Expenditure on Technical Education (Rs crores in current prices)				
	1993-94	2001-02	2002-03RE	2003-04BE
Total	405.2	1241.8	1349.1	1544.9
IITs	142.1	517.5	588.0	589.0
IIMs	17.5	102.4	72.2	74.7
IISc	51.6	100.0	110.0	99.0
AICTE	2.4	108.6	120.0	130.0
RECs	72.5	139.7	190.1	216.7
Others	119.1	273.7	268.7	435.5
Source: *Analysis of Budgeted Expenditure on Education* (various years)				

Source: CABE Report on Funding of Higher Education, Mungekar [5]

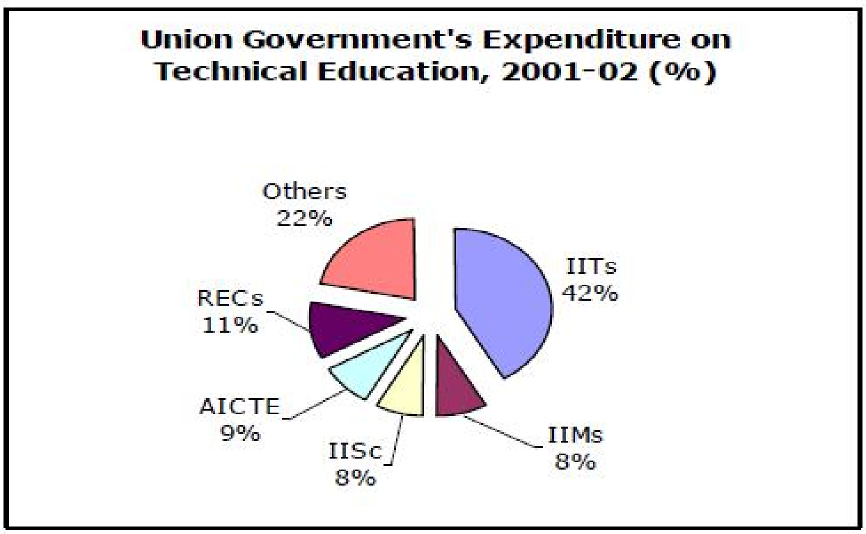


Figure 13: Govt. Of India expenditure on Technical Education (2001-02)

Table 9: Indian Government's Expenditure on Higher and Technical Education as a proportion of GNP [5].

Higher Education: Relative Priorities				
	Government Expenditure on Higher Education as		Government Expenditure on Technical Education as	
	% of GNP	% of Total Government Revenue Expenditure	% of GNP	% of Total Government Revenue Expenditure
1990-91	0.46	1.58	015	0.51
1991-92	0.42	1.43	0.14	0.48
1992-93	0.41	1.42	0.14	0.48
1993-94	0.40	1.42	0.13	1.47
1994-95	0.39	1.40	0.13	0.47
1995-96	0.37	1.35	0.12	0.45
1996-97	0.35	1.30	0.12	0.44
1997-98	0.35	1.31	0.12	0.44
1998-99	0.43	1.39	0.13	0.47
1999-2000	0.47	1.61	0.14	0.48
2000-01	0.49	1.61	0.13	0.44
2001-02	039	131	0.12	0.41
2002-03RE	0.40	128	0.13	0.41
2003-04BE	0.37	1.23	0.13	0.42
Source: Based on *Analysis of Budget Expenditure on Education* (various years).				

As a matter of policy the Government of India is committed to enhance its share of involvement in offering quality technical education at UG and PG levels. Further, the policy of the Government is to significantly enhance the access of technical education by making significant increase in intake at UG and PG levels in the government as well as in the large private sector, still growing in India. The policy of the government is also to ensure access to technical education to the SC / ST, OBC and other weaker sections of the society. This is being pursued by the government as a social obligation to improve the livelihood of the weaker sections. Technical education is seen as a major enabler to uplift the living standards of the families which have capability to send their children for technical education in India's engineering institutions. The rising levels of the middle class and weaker sections in India are a direct outcome of empowerment provided by increased opportunities of technical education in India.

The government of India, recognising the need to address the challenges of the new millennium and to prepare India's advancement on the pathways of a knowledge society has established the National Knowledge Commission headed by Dr. Sam Pitroda, to revisit India's higher and technical education to identify major reforms to be carried out to significantly enhance the quality of output as also to strengthen India's contribution to intellectual property and global knowledge power.

6. Promotion of Research & Industrial Interaction

6.1 Research in Technological Universities and Institutions.

Learning to learn, learning to do, learning to be (useful) and learning to live together continue to be the fundamentals of any good education. The advent of the 21st century has, however, ushered in paradigmatic changes and shifts in our concept and practice of education in general and engineering education in particular. The driving force behind these (and others related to technomic-globalisation) is the "Knowledge Power" which is the power to create and innovate usable and exploitable scientific information to provide new, cheaper, efficient and sustainable solutions for mankind. It is a multimodal and multidimensional process based on a combination of a variety of sciences, engineering skills, technologies, marketing, manufacturing and management. Knowledge is evolving as an explicit rather than a tacit force is increasing rapidly and yet also becoming obsolete just as rapidly, is a tradable and marketable commodity protected internationally by IPR laws. The economic growth of any society is now increasingly dependent on" creativity through human resources, innovation through research and development, and capital through intellectual property rights". Consequently, besides diffusion and assimilation of knowledge, creation of knowledge through research and development must be an integral component of any engineering education.

Research is to conduct scholarly inquiry, develop, create, innovate or discover something hitherto unknown yielding an intellectual outcome to enhance our knowledge of nature in its various living and non-living manifestations of processes and products, and which may benefit the society in some tangible or intangible ways. Whether research by engineering faculty should be rigorous or relevant, basic or applied, business driven or technology/knowledge driven has been debated much. In fact, the generally accepted concept of linear chain connecting basic science with applied science to engineering and technology is not necessarily valid in the prevailing knowledge era. Therefore, for engineering education, a broad definition of research involving scholarly investigation or inquiry resulting in a product or process or leading to intellectually stimulating knowledge ambience is generally acceptable today.

Prof. J.C. Ghosh, a former director of IIT Kharagpur, told a group of teachers that teaching without research is like a stagnant pool of water, which, after sometime, is likely to stink. It is now universally accepted that teaching and research must go together whether good teachers are good researchers and vice versa has been debated often. It is generally concluded on the basis of experience that research correlates positively with teaching efficiencies and researchers are relatively more committed and inspiring teachers. Besides, research in various forms is of considerable interest to a faculty member for a variety of other reasons such as:

- To update, broaden and enhance knowledge capital and analytical skills of the faculty
- To enhance self-confidence and professional respect and recognition among peers at home and abroad
- To stimulate creative teaching-learning experience
- To become an inspiring teacher
- To broaden and enhance knowledge capital and analytical skills of research students
- To nurture research students with the spirit of working together on research problems in a group effort
- To nurture and mentor students to become the next generation faculty
- To be available as a “think tank” to serve country, industry and society

- To create entrepreneurs to support the creativity chain
- To interact with industry through research or consultancy on real life problems for mutual professional and financial benefits
- To participate in national and international conferences for exchange of ideas
- To undertake consultancy work for intellectual and economic benefits
- To earn economic benefits in terms of recognition, fellowships of academies, awards and rewards
- To bring laurels to ones institution and thus create its brand image differentiation

What Type of Research?

A relevant and mission mode research is, of course, of great economic value to the society. Nevertheless, any type of scholarly inquiry and research, whether basic or applied, theoretical or experimental, which leads to creating intellectual capital are not only desirable but vitally important for engineering education.

Broadly speaking, typical areas of research are:

- Study of natural phenomena and their applications in any area of science be it physical, mechanical, chemical , metallurgical ,biological, medical, agricultural , cross disciplinary, multidisciplinary etc which may lead to refereed publications in respected journals, new knowledge, improve existing engineering practices ,processes or products, patent disclosures, or a useful databank
- Design /develop/ fabricate, on a laboratory/pilot plant scale, processes, products, devices, equipment etc for teaching ,research, industry or society at large

- Interact/ consult with industry, civic authorities and service providers to improve / innovate / create processes/products
- Write stimulating research and text books
- Create inspiring and stimulating teaching-learning materials, equipment and techniques
- Interact with industry through research and/or consultancy on result / mission oriented problems for mutual benefit.

Present Scenario:

Despite several comprehensive reports on technical education in the country in the recent past , it is most unfortunate that no reliable and credible primary or even secondary data on the input and output of research or research oriented education in engineering institutions in India exists at present. The most recent Knowledge Commission Report and the Observer Research Foundation funded report of Professors Rangan Banerjee and Vinayak Mulley [5] are some of the best efforts to analyze data based on commonsense extrapolations. However, it needs to be pointed out that, within the last two years of these reports ,due to rapid (over 50%) expansion of the number of engineering colleges (largely private) to over 1900, and with over 150 private Deemed-to-be technical universities in the year 2008, the intake capacity has exceeded 8 lakhs and thus data in these reports is already outdated. Besides engineering colleges, education at degree level is also offered by many of the over 250 state and central universities, as also by 12 IITs, IISc, five IIITs , 22 NITs, some specialized institutions and even some polytechnics. Out of over 4 lakh engineering graduates during year 2006, national institutes like IITs and NITs contribute about 3%. In general, as per the BM report, IIT grads do not opt for MTech or PhD at IIT as almost all IIT graduates get jobs before they actually get their degrees. A large no of these graduates will sooner or later go abroad (primarily to USA) for higher studies. A small fraction of less than 2% will join post graduate programmes in Indian institutions, in particular IITs and NITs.A still smaller (about 1%) fraction thereof will join PhD programmes. Top institutes like IITs and IIScs contributed less than 1% of the engineering grads, 20% of the MTechs and

40% of PhDs. A majority of these graduates pass out from the National Institutes of Technology (3%), state engineering colleges and private engineering colleges (75%).

Despite all these mind boggling numbers of our academic institutions and the graduates, the annual number of engineering PhDs is less than 1,000 which is less that 1% of graduating MTechs in the country It is very likely that this number of engineering PhDs also includes doctorates from several applied science and science-engineering interdisciplinary areas. It is noteworthy that, in the US, more than a third of all PhD degrees in science and engineering and almost half of all doctorates in mathematics and computer science are awarded to non-US students, with Indians accounting for 10% of science and engineering doctorates. Between 1998 and 2001, with biomedical engineering (16.3%), aerospace (12.8%) and computers (7.7%). These numbers have increased substantially in the last few years.

The preceding information make it clear that a very large majority of our engineering institutions have failed to evolve from undergraduate teaching to post graduate teaching and research at MTech and Doctoral levels. The vast majority of private engineering institutions are primarily first degree level ones and have made little effort to introduce research oriented programmes for economic reasons as also for lack of qualified faculty. Clearly, the engineering education system in India has been unable to attract the best engineering students for post-graduate studies. Even the IITs are unable to attract their own engineering graduates and postgraduates for their doctoral theses. The BM study shows that only 1% of the graduating BTech class of an IIT opts for an MTech and only 2% of the graduating MTech class opts for a PhD..

Even the IITs have failed to meet the objectives of research oriented institutions and take up the role of “Think Tanks” as was envisioned by the founders. The percentage of faculty engaged in serious research in any of the IITs is around 30 %.An analysis (such as done by the Institute of Scientific Information (ISI), USA)of the research publications per faculty in IITs is around 1 as compared with over 6 of MIT faculty. Even worse, the citation index and impact factors of IIT publications places the IIT faculty are well below the achievements of globally known technical institutions in the western world , as also China and South Korea. This situation has been prevailing despite the “publish or perish” rule for promotions in the IIT system. The situation about research in most other public and private institutions is too pathetic to talk about. The challenge for the IIT system, as also NITs and Technical Universities, is to enhance their overall output considerably so as to be able to impact the engineering education system and its research contributions.

Premier institutions are also expected to contribute to patents and industrial consultancy practice. Any interest in these activities is a relatively new phenomenon within the last two decades or so. Advice of “patent before publish” has encouraged some faculty in premier institutions to file patent applications. The total number of patents filed per year by all of our national academic institutions does not exceed 100 as yet. The number of patents which have been utilized, although not known precisely, is insignificant. As regards consultancy, the practice hardly exists in most institutions except for IITs and a few other premier institutions. The number of faculty participating in consultancy services even in IITs is rather small, probably less than 10 %.

Funding of Research:

Funding for all R&D activities in the country is mostly by the departments of the government of India and is less than 1% of the GDP which is one third of what Korea spends , and certainly much less than what most developed nations spend. The Indian industry is known to contribute about 20% of the total R&D funds which are primarily for the in-house activities and is much smaller than what industry spends in developed countries. A significant part of government R&D funds is being given to engineering education through a whole variety of schemes of a dozen or so S&T funding agencies / departments/ministries of the government of India. As an example ,in addition to the budget of over 100 crore for the older IITs given by the GoI today as plan and non-plan funds , each IIT manages to get sponsored R&D projects worth 20-50 crores every year. The end result of these projects is a report, few publications and a PhD or two. There is not much correlation of the promised outcome with the outlays of these projects, particularly the massively funded so-called "Nationally Coordinated" projects. Clearly, money alone does not produce R&D in India. In sharp contrast, our own postgraduate students and PhDs are well known to be very productive in western academic institutions and infact are an important source of intellectual capital of USA. Our students also do very well even in the research laboratories of multinationals in India.

Why our R&D is not productive has been debated often enough by funding agencies and yet the situation has not changed much because bureaucracy (both of the funding agencies and receiving institutions) has yet to create a proper mindset and appreciate the need to function in a "business-like" manner. Some related observations are:

(a) It is most unfortunate that there is no available database of the names of the investigators, sponsored projects and their outcome in the country. The funding agencies do not bother to share information even in overlapping areas of R&D let alone work together even loosely. As a result, it is not uncommon for an experienced faculty well versed with the "technology" of getting funded to get substantial funds for the same or similar project from more than one agency.

(b) The funding agencies have rarely made an effort to solicit or invite competitive proposals for nationally important projects.

(c) After going through the hassles of submitting a project and getting its approval which can easily take one or more years, the miserly release of funds in protracted phases by the agency and its poorly planned utilization presents horrifying, challenging and time consuming experience for any investigator.

(d) Most of the funds are spent on importing equipment and even simple chemicals and other materials which could have been and should have been produced in India if the funding agency pursues such a strategy diligently with a generous and liberal policy.

(e) Only a few funding agencies conduct one or two reviews and assessment of the progress of the project through selected peers. Just how seriously this process is taken is obvious from the fact that very very rarely has any project ever been cancelled for want of any outcome or the investigator reprimanded or blacklisted.

(f) The problems associated with all aspects of sponsored projects are many and must be solved if research has to become an attractive, effective and satisfying experience for any engineering faculty. A paradigm shift of a transparent, flexible, liberal, pragmatic, accountable and autonomous system is the need of the hour.

6.2 Academia-Industry Interaction

Interaction between academia and industry in India in the form of joint or collaborative R&D projects has been rather insignificant in the recent past partly because the confidence level between the two is very low and largely because the Indian industry, with some exceptions, is short-sighted and has short term goal of making profit by adopting or by buying whatever technology is available elsewhere. Academia has also not been enthusiastic to develop interaction even though it is generally accepted that stronger academic engagement with industry improves and strengthens basic research.

The research profiles of industry and academia are expected to be vastly different and thus have little overlap. Very briefly ,academic research is characterized to be : Scientific ; Open-ended ; Long term; Unconstrained ; Knowledge generator ; Analytical; Peer reviewed ; Degree requirement based; Human resource development oriented; Publication oriented; Constrained by financial and infrastructural resources.

On the other hand ,industrial research has its own identity as : Need based ; Focused, Short term ;Real world problem; Professionally executed and managed ; Viable product / process/ application and profit oriented. If so, how can the two meet to collaborate fruitfully?

Collaboration between two or more partners requires a driving force derived from shared values, challenges or threats, and tangible benefits. Internationalization of research and knowledge industries has provided the required driving force. Economic power is being increasingly determined by knowledge and innovation created and nurtured by knowledge institutions. The industry has begun to recognize such paradigm shifts as:

- Internationalization of knowledge and innovation driven technologies
- Globalized competitiveness
- Global concern for sustainability/ greenness
- Globally protected IPR regime
- Globalized markets
- Rapid obsolescence; shorter life cycles of products and processes
- Global outsourcing

These evolving phenomena have called for a close interaction and collaboration of knowledge institutions with industry, entrepreneurs, society and market .Indeed, the interaction has become essential for the survival and growth of both the academia and industry in a highly competitive world. There is thus, a strong need to promote interaction between institution and institution, I&I, Universities and Universities, U&U and Industry and Universities, I&U. This requires creating enabling environment for distributed research initiatives, spread over a number of institutions and universities, partnership of the industry right from conceptualisation of R&D projects and participation of the students even at UG levels in research and development.

6.3 Status of Collaboration:

- Industry sponsored R&D projects in academic institutions are not very common even today. On the other hand , spurred by the example of alumni of IIT Kharagpur setting up a research centre on telecommunications, alumni of other IITs and some industries have come forward to set up a few research centres in each of the IITs primarily in electronics , communication and IT areas. However, meaningful collaborative research in these centres is still not forthcoming as a matter of strategy.

- After persistent efforts, IIT Kharagpur managed to get several industry sponsored Chair professorships. Since then, all IITs have a large number of such Chair Professorships created by alumni and industry. Unfortunately, these Chairs have not yet been instrumental in creating any industry-academia collaborative R&D programmes.

- During 90s, Planning Commission sponsored a very promising venture of Mission Mode Technology Projects to be undertaken jointly by IITs and industry. It took over two years of meetings and presentations to get funds released from the government by which time much of the enthusiasm of collaborating industries vanished. This is an example of an excellent concept which got nipped in the bud, thanks to the Indian red tape. The Technology Development Board, TIFAC, etc are other agencies which are expected to nurture academia-industry interaction. The results so far are, however, not very inviting for a variety of administrative reasons.

- Industrial consultancy is being increasingly appreciated both by the faculty and the concerned industry though it is confined to only few institutions and that too to a very few senior faculty members.

- The Department of Science and Technology (DST) has initiated several programmes for industrial product/process oriented R&D based on knowledge created by associated academic institutions. Presently taken care by its National Science and Technology Entrepreneur Board(NSTEB), there are 15 Science and Technology Entrepreneurship Parks (STEPS) in the country compared to over 500 in China and over 50 in a tiny country of Israel. Only 5 of these STEPS are presently doing reasonably well and are nearly self supporting.

- Under the DST programme, IIT Kharagpur was the first IIT to set up a successful STEP on 100 acre land donated by the state government. The institute liberalised rules of governance of the park and allowed selected faculty members to set up enterprises despite opposition and warnings from the central and state government. Several equity based joint ventures were also initiated with some industries. This model of allowing faculty to set up joint ventures along with their colleagues, students and industry on the basis of their research interests has now been adopted by all IITs and many public and private engineering institutions. All IITs have now established their own versions of STEP, Entrepreneurship Development Cells (EDC), or Technology Business Incubators (TBIU), etc. Also, over 150 EDCs or TBIUs have now been approved by NSTEB in various engineering colleges and universities. Besides, DST several other government departments (such as MIT, DSIR, MHRD, UGC) have now come forward to support such entrepreneurial activities in academic institutions. The involvement of industry in such ventures is still rather limited.

- Challenging young persons to become Technology or Knowledge entrepreneurs to translate their dreams to action is a very important investment for any knowledge society. Though a far sighted experiment by DST and other agencies,, its success so far is very limited and it needs a lot of refining and tuning particularly (a) in the mode of operation both by the funding agency and the associated institutions , (b) in terms of hand holding of entrepreneurs liberally by way of providing grants , venture capital and infrastructural facilities, and (c) in assuring transparency, ethical conduct , and protection and marketing of intellectual property.

7. Innovation and Entrepreneurship

The process of developing and fostering proof-of-the concept, and/or building an old business/undertaking out of innovative ideas is termed “entrepreneurship”. A techno-preneur is an entrepreneur who creates and innovates on the basis of scientific and engineering knowledge to build something of recognized value to society around perceived opportunities. It is important to keep in mind that entrepreneurship is not a job but a spirit of creativity, innovation, adventure, challenge, excitement, and achievement.

The old industrial economy has been run by the power of Money, Manpower, Machinery, Materials and Methods – the so-called 5M's. The new emerging economy of the present century is being largely determined by the Mind power, the 6^{th} M. In this changing scenario , only the most adaptable to mind power will survive .As a result of globalization of science, engineering and manufacturing technologies, trade and markets , business practices and services , a significant shift of emphasis from a decaying industrial economy composed of large firms to a knowledge-based entrepreneurial economy driven by knowledge based innovative technologies has taken place. Rapid changes in technology and innovations have lead to shorter product cycle, and strong emphasize on quality, environment standards, sustainability, IPR, and other issues. With the availability of various financing options, entrepreneurial activity is gaining momentum worldwide. Higher education institutions are becoming an important link in the innovation cycle and in promotion of entrepreneurial instruments. Growth of global economies and life styles of civilized societies are being increasingly determined by knowledge and innovation created and nurtured by knowledge institutions. Close interaction of such institutions with entrepreneurs, communities and industry has therefore to be made mandatory

Entrepreneurship strengthens the knowledge system, converts knowledge to intellectual property, promotes techno-ventures for commercialization of technologies, creates wealth and enhances technology competitiveness and the tech-image of the country. Further, it creates new business and creative opportunities, jobs and services, and thus promotes regional/ local development. The shining example of the one trillion dollar economy created and nurtured by the Innovative Machines of the Silicon Valleys of the world are a testimony to the spirit of entrepreneurship which are well documented by the World Bank reports. Entrepreneurs in Silicon Valley, USA create literally several new firms and new millionaires through IPO a week.

Mechanisms to Nurture Innovation and Techno-preneurship

Recognising the important role of entrepreneurs in the economic growth, the concept of Science & Technology Parks and Incubators originated in USA during 1950s. Today, USA has over 1000, China has over 500, and Germany has over such platforms. The concept originated in India during 1980s. Presently, India has 13 S&T Entrepreneurship (STEP) parks, and some 50 Incubators of different types which have been funded by the National S&T Entrepreneurship Development Board of the Department of S&T (DST), Government of India. More recently, Department of Biotechnology (DBT), Ministry of Information and Technology (MIT), and Ministry of HRD have taken keen interest in sponsoring and supporting similar platforms for entrepreneurship in similar or specialized areas. Whereas IIT, Kharagpur manages a 100 acre area STEP , other IITs have suitable platforms akin to Incubators. With a very few exceptions , over 2000 private engineering colleges and technical universities and university departments have not yet started any entrepreneuship activity.

The variety of platforms created all over the world to nurture entrepreneurship includes:

Research Parks, Technology Parks, Science & Technology Entrepreneurship Parks (STEP), Entrepreneurship Development Cells, Industrial Parks, Innovation Centres, Technology Incubators, Technology Business Incubators, Business Incubators, and Specialised Parks (such as Biotech, Information Technology, Electronics Parks).

A brief description of the functions of some of these entities follows:

- Research Park provides a physical environment for interaction between academics, researchers, commercial organisations and entrepreneurs to advance scientific and technological knowledge. Manufacturing except generation of prototypes is prohibited

- Science Park provides affiliations with academia and research institutions with emphasis on development work, prototype production and technology transfer

- Technology Park provides Proximity to university, research institutes, applied research and manufacturing focus, and commercial application of advanced technologies.

- Business Incubator is an economic development tool for occupants not limited to techno-preneurs, providing shared office services and specialist services which help improved growth rate with reduced failure rate.

- Technology Business Incubator (TBI) is a low cost facility to incubate technological ideas or develop technologies of products / processes for commercialization in the market place. It helps the young firms to survive and grow faster by providing them with specialised technical, financial, management and marketing support services during the critical period of the start-up phase of a business venture.

Depending on the type of activities , Incubators are further classified as :University Incubator having incubates primarily from the faculty, students and alumni ; Regional or Rural Incubator , having incubates who are interested only in rural-based relevant technologies ;Single Business Incubator which houses incubates with one common business interest ; and Virtual and Semi-Virtual Incubator which do not provide in-house services to the invitees but allow access to mentoring , advisory and consultancy processes

Whatever be the nomenclature, all have a common core objective which is to nurture entrepreneurship in collaboration with institutions of higher learning, research and development. More successful ones have flexible and pragmatic policies with a broader perspective and are just called incubators or TBIs which allow an incubi to move seamlessly from a concept to pilot scale production and commercialization in the same place before moving out of the incubator.

The IITs and some selected premier institutions of engineering such as Delhi College of Engineering have succeeded in creating a culture of innovation. DCE Hybrid Car, DCE Super Mileage Vehicle, DCE Unmanned Aerial Vehicle, DCE Solar Car, DCE Moon Buggy and DCE Autonomous Underwater Vehicle all designed and developed by inter-disciplinary student teams under guidance of the faculty have received high international acclaim. The need however, is to take such innovations to market. This requires creating necessary mechanisms and structures including partnership with venture companies to shape the proto-types and laboratory level innovations to the industry accepted designs and innovative products. This is where the importance of establishment of S&T Parks, Knowledge Parks and Entrepreneurship Parks lies in equipping Universities and Institutions with the necessary enabling environment and support services.

Despite the efforts of the NSTEB, entrepreneurial activities in India are still in the infancy stage. Clearly, some attractive incentives are required to accelerate the process so that most technical academic institutions in the country would have an active incubation centre. Both the government and the academic institutions must recognize the importance of this sort of activity and adopt significant measures to activate and popularize it.

8. Role of Professional Societies and Academies

Engineering education in India is a system of well-structured learning and training process in major and traditional engineering disciplines. The Information Technology (IT) and Communication Technology (CT) waves have had a major impact on the curricula of even the conventional disciplines. With the emergence of globalised service sector in IT and CT areas, and the requirement of multi-skilled engineers ready to work in industrial jobs, the engineering education system has gone through major changes. In this process of transformation, professional institutions have a major role to play.

India has three Science Academies, namely Indian National Science Academy, Indian Academy of Science , and National Academy of Science (which despite the name also include Fellows from engineering professions), one Indian National Academy of Engineering .These Academies recognise professional achievements of individuals by electing them as Fellows, hold seminars and workshops in selected emerging areas and publish status reports, nurture scientific and engineering temper, R&D activities and industry-academic interaction through a variety of programmes.

Quoting the words of the National Knowledge Commission, “most engineering graduates do not possess the skills needed to compete in the economy, and industries have been facing a skills’ deficit”. Just how to balance rigorous academic training of an engineer versus preparing him for industry-readiness is a matter of concern to both academic institutions and professional bodies such as institutes, societies, councils and academies. Most professional disciplines have their own apex body to interact with academic institutions, to offer advice and appropriate training courses for upgrading knowledge as also degree qualifications. Re-engineering engineering profession to meet the evolving requirements of the profession is thus an important objective of these bodies.

The present engineering education and the skills imparted are not adequate enough to meet new and emerging challenges of internationally acceptable equality of capabilities which is required for international mobility in the WTO environment .Further, in the absence of an Engineers Act, the engineering profession has no legal status. Since India is not a member of Engineers Mobility Forum, and only a provisional member of the Washington Accord, recognition of our Engineering degrees abroad is not automatic. Of course, being a brand by themselves, the degrees from IITs and many other prominent engineering institutions in the country such as BITS Pilani, Delhi College of Engineering, Technological Universities and NITs are generally recognised the world over.

Steps are now being taken by the National Bureau of Accreditation, NBA of AICTE to obtain permanent membership of the Washington Accord. An Engineers Bill has been drafted by the Engineering Council of India (ECI) ,an apex body of some 25 professional associations, societies , councils and institutions such as Institution of Engineers, Institution of Electronics and Telecommunication Engineers , Institute of Chemical Engineers, Computer Society of India , Consulting Engineers Association of India , etc covering almost all disciplines.. The bill , presently pending with the Government of India, proposes a statutory body to register and license engineers. The ECI aims at becoming a representative of professional associations which will accord recognition of professional qualification and experience, bring about discipline and accountability, and monitor ethical conduct among professionals. Presently, the ECI organises national conventions and conferences on issues related to the practice of the professions.

A professional is expected to contribute to the progress and well being of society in a sustainable environment through creation and dissemination of knowledge, and by using engineering knowledge and skills to develop technologies, products and services, as well as regulatory mechanisms. All these activities must be consistent with a universally acceptable code of conduct. Defining ethical values and code of conduct and to ensure adherence thereof is also a concern of the professional bodies. Some bodies such as Institution of Engineers and Indian Academy of Science have adopted such codes of conduct for their members.

9. Looking Ahead – Reforms Needed, Opportunities and Threats

India's transformation into a knowledge society and further strengthening its rapidly growing economy necessitates far reaching reforms in technical education. These reforms have been deliberated in great detail by the NKC (National Knowledge Commission) of India.

The National Knowledge Commission in its recommendation to the nation has suggested major reforms and made recommendations for adaptation by the Indian Universities and institutions. Some of the major reforms suggested by the NKC of India are :

1. **Curriculum reforms** to make engineering and technology curriculum more industry relevant, tuned to current and future needs and having necessary mechanisms and structures for periodic review and up-gradation. Major involvement of industry in formulation of curriculum and greater flexibility in approach is recommended by the NKC.

2. The NKC has further recommended that the curriculum design should **promote interdisciplinary engineering** and facilitate movement from one Department to another, as per the interest and capabilities of the students. The credit transfer facility should also be provided for students to complete a course of study in more than one University.

3. The NKC has also recommended that **synergy between education and research** should be created in the educational institutions to promote culture of research and innovations.

4. The NKC has also recommended a greater **focus on PG and research** in engineering and technology institutions.

5. Another major recommendation of the NKC is that the large affiliating University system should be replaced by **smaller Universities** and giving **academic and administrative autonomy to the institutions**.

6. The NKC has recommended **differential pay package to reward performance** of the faculty.

The NKC has recommended that the foreign Universities should be allowed entry into India and Indian Institutions and Universities should marked the education abroad on a level play field.

Further, in order to understand what needs to be done to strengthen India's Post-graduate education and research in engineering and technology, we need to analyze why US institutions are a magnet to postgraduate students from all over the world, including India. Recognizing that Knowledge is the driver of new economies world over, the policies of the US (as also several other advanced western countries) government, the academic institutions as well as knowledge industries are periodically tuned to offer very attractive research ecologies to attract and retain some of the best talents of the rest of the world. Well paying fellowships, excellent research facilities, stimulating environ, competitive, challenging and relevant research, and opportunity to work and to be absorbed by the industry are indeed very attractive prepositions. If India wants its best graduates to do postgraduate studies and research in its premier institutions, it has to compete with western countries in providing comparable facilities, environment and opportunities.

Some measures for consideration by Indian institutions are:

- Institutions must focus on strengthening knowledge infrastructure including connectivity, networks and establishing working alliances and collaboration between Universities in India, between Indian Universities and Foreign Institutions and Universities.

- Facilities such as world class research centres, transforming some of the laboratories as world class test houses and industry sponsored training centres shall strengthen the cause of synergy between education and research and promote industry academia partnership.

- Critical shortage of qualified and research oriented faculty which, besides undertaking R&D activities, will nurture the future generation of qualified faculty needs to be addressed to by all technical universities and premier engineering colleges by initiating post graduate and doctoral programmes and by systematic mentoring

- PhD level research guidance should be allowed to only competent faculty members duly recognised for their research integrity and scholarship and research scholars should be encouraged to be pursued seamlessly among different departments.

- Research publications arising out of publically supported projects and summary of M.Tech and PhD thesis should be made available as an "Open Access" on an appropriate website of the institution or any regulating agency designated for the purpose. This practice will stimulate competition, and prevent duplication as well as plagiarism

- Faculty should enjoy full autonomy with accountability for bidding and for executing research projects in a hassle free manner and should be allowed financial incentives, in addition to their salaries, from sponsored R&D and consultancy projects.

- Institutional mechanism for peer review of R&D projects and assessment of return including intellectual capital generated should be established.

Another major area of reform relates to strengthening industry academia partnership in higher education and research. It is suggested that a number of meaningful measures are needed to create a vibrant environment of industry academia interaction in Indian Engineering Institutions. Some suggestions are:

- Establishing Chairs by the industry for industrial R&D and training and school finishing programmes

- Periodic short or long term exchange visits of faculty and industry professionals
- Appointment of Adjunct Faculty from industry by recognizing equivalence of industrial experience with MTech and PhD degrees
- Industry sponsored R&D projects
- Industry sponsored postgraduate and research Fellowships
- Short term training programmes for students in industry and for industry personnel in academia
- Development of sandwich programmes for earning a degree by employed persons
- Organisation of joint seminars, workshops, special lectures
- Sharing the use of expensive and sophisticated test and analytical facilities
- Development of curricula and new topics for learning
- Participation in evaluation of theses, research projects
- Undertake joint sponsored R&D projects, involve industries in innovative product and new technology development.
- Participation in S&T parks, Entrepreneur development cells , Technology business incubators, Research consortia, Innovation Promotion Groups , etc
- Promote student and faculty led small and medium knowledge enterprises and establish joint S&T based industrial enterprises with equity participation
- Establish innovation and technology development foundation.
- Integrate ethics, sustainability and social responsibility in engineering education as also in the conduct and pursuit of R&D.

- Initiate collaboration between industry , academia, professional institutions, and science and engineering academies to develop a database on a common website to provide information and to highlight the scope and achievements of sponsored R&D projects

- Establish a Think-Tank jointly with all stakeholders to assess and forecast emerging trends in engineering education , R&D and technologies

10. Concluding Remarks

Academics are one of the most important pillars of the evolving Knowledge Society. And, to survive, compete and thrive in the technomic globalization era, a Knowledge Society depends on creativity and innovations of the Knowledge disseminators and creators. The academic institutions, government S&T funding agencies and industries have a high stake in working together to usher in a new era of liberal, flexible and pragmatic governance and financial rules and regulations for conducting relevant and meaningful R&D in academic institutions. India's technical education has done a lot of good to nation's economy, provided a major support to the advanced nations for their IT industry and for outsourcing their ITES related services from India. India has thrived on the capabilities of its human resource nurtured in its leading institutions, Indian techies and Indian entrepreneurs in India and abroad have earned a high reputation for their enterprising spirit, ingenuity and technological capabilities. However, the rapid expansion of technical education in the post-liberalisation era has thrown open new challenges including meeting the growing shortage of qualified and experienced faculty, on one hand and controlling the mushrooming growth of private business like technical institutions.

The challenge lies in implementing major reforms, some of them identified in this report to rewrite the map of technical education in India, responsive enough to the calls of globally accredited quality of its human resource output, quality research enforcing research integrity, accelerating pace of innovations and development and protection of intellectual property. India can do it and it should succeed in doing so if it has to create and retain Advantage India in technical education in the new knowledge age.

The Indian Government regards highly skilled human capital as the major resource to provide the continued propulsive thrust to the growth of knowledge-based economy and recognizes major opportunities for further up-gradation of its large technical education infrastructure. It has taken strides into enhancing Government contribution to quality technical education and research by establishing 08 new IITs, 07 IIMs, 15 Central Universities, 10 NITs, 05 IISERs and 20 IIITs during 2008-09. Major reforms as identified by the NKC and by the National Academies are being taken up on priority to significantly enhance the quality as well as quantum of India's technical education in the coming years.

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References:

[1] India Vision 2020 - Towards a knowledge society.

[2] National Knowledge Commission Reports to the Nation 2006 and 2007.

[3] U.R. Rao, UG Review Committee of AICTE “Revitalising Technical Education”, 2005.

[4] Rangan Banerjee, Vinayak P. Muley, “Engineering Education in India” report on review sponsored by Observer Research Foundation, 2008.

[5] CABE Report on “Funding of Higher Education in India”, Mungekar 2005.

[6] G Biswas, K L Chopra, CS Jha and DV Singh, “Profile of Engineering Education in India : Status,Concerns and Recommendations”, AICTE Publication ,2009

[7] AICTE Publication, “Technical Education in Independent India 1947-1997”, Compiled by P Gupta,KL Chopra and SK Suri,1999

[8] R Natrajan,”Emerging Trends in Higher Education and Indian Scenario”,2002

[9] Pawan Agarwal “Higher Education in India : The need for change”, 2006

[10] PB Sharma, “Knowledge Power in Higher Technical Education” DCE Publication, 2008

[11] Rama Rao, ”Reshaping Postgraduate Education in Engineering and Technology”,1995

[12] INAE Report to the Parliamentry Committee, “Salient Issues in Higher Technical Education”, Dec 2005

[13] PB Sharma (Ed) “Engineering Education: Vision for a Better Tomorrow”, Special Issue, AIU Vol 43, Sept 2005.

[14] K.L. Chopra and R.K. Suri, “Knowledge Based Technical Education”, Special issue, AIU, Vol III, No. 39, pp. 42 – 47, 2005.

[15] C.S. Jha, “Global Issues in Engineering Education”, Special issue, AIU, Vol III, No. 39, pp. 13 – 19, 2005.

[16] RA Mashelkar, “Strategic Roadmap for Academic Excellence for Future RECs”, Report of High Power Committee on RECs to MHRD, 1998.