Chapter 5
Engineering Education in India: A Comprehensive Overview

Balasundaram Subramanian

Abstract This chapter is an attempt to survey the steady evolution of engineering education in India from colonial times to the present in terms of institutional landmarks and defining moments in Indian history. The survey urges that engineering education in India, especially in its contemporary reflexes, has to be understood against the backdrop of periodic reviews, reforms, recommendations of various committees and the compulsive social, economic and political matrix informing policy-making. In particular, it highlights the achievements as well as the shortcomings of the concerted attempts to consolidate teaching and research in keeping with the imperatives of national objectives and market needs. It reviews reform initiatives in recent times, and it locates in the convergence of the technical sciences and the liberal arts disciplines the potential for improving human resources in India.

Keywords Colonial history • Engineering education • Knowledge economy • Policy-making • Reforms

The Colonial Interlude

> We have no enemy now in India, except popular ignorance, and that we are doing our best to remove by the most complete system of State education that has yet been devised in any country (J. G. Medley, Principal (1863–1871), Thomason College of Engineering, Roorkee).

Engineering Education in India, to borrow an expression from Leibniz, is heavy with the past and big with the future. To understand the cumulative presence of the past, one has to go back to the colonial interlude, which marks India's inexorable march toward modernity and westernization. From 1773 onward, colonial dispensation in India comes increasingly under imperial supervision; with Crown rule replacing Company Raj after the Great Mutiny of 1857, a complex canvas of administration

B. Subramanian (✉)
School of Humanities & Social Sciences, Indian Institute of Technology Mandi
(Kamand Campus), 175005 Katola P.O., Himachal Pradesh, India
e-mail: bs@iitmandi.ac.in

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emerges, scripting India's progress to a welfare state and ultimate self-determination with Benthamite efficiency. It is a passage assisted no doubt by the massive influx of technology in the wake of the industrial revolution, with steam navigation, railroads, roads and telegraphs decisively influencing the emergence of India as nation-state. It is indeed a passage that goes hand in hand with the establishment of a heavily centralized public administration. Centralization – the root impulse to organize in order to manage – may have tended to go against the grain of a certain native disposition of managing not to organize at all – a trait that had once prompted John K. Galbraith to brand famously India as a "functioning anarchy". Nevertheless, it cannot be gainsaid, that it was predominantly a growing class educated on western lines that propagated widely and instilled firmly the notions of nationalism and democracy in the country.

Besides the unifying effect of education in the English tongue, education fitting the needs of this vast centralized system of law and administration emerges as major instrument of social change. Also, transfer of technology makes its own set of institutional demands for the organization and advancement of knowledge altogether different from its traditional transmission within the confines of caste-based professional networking. Progressively, choice of profession is influenced by economic considerations rather than by caste affiliation, viz., by ascription to birth in a certain group or community. More importantly, exposure to the new education enabled Indian intellectuals to reflect critically on a moribund tradition, its mores and values and to revive its quintessential civilizational cementing force by a process of progressive reform. This dialectic of the foreign and the familiar leading to a virtual renaissance of Indian culture, especially in Bengal, was prompted no doubt by the reformist bid to establish educational institutions like the Hindu College in 1817 in Calcutta, modeled on western curricular structure. Notably, this preceded the famous Macaulay Minute of 1835 (Subramanian 2010, p. 165) that makes a complete departure from native educational systems and catapults India onto the trajectory of western education in the English medium through government schools and complemented by a complete range of subjects in the arts and the sciences.

An even more significant milestone was Sir Charles Wood's Education Despatch of 1854, "which sets out a blueprint for the future development of western education throughout British India. It included provision for the establishment of provincial education departments, government and voluntary schools, and universities based on the London model of affiliated colleges in Calcutta, Madras and Bombay" (Whitehead 2003, p. 5). Soon after India becomes Crown Colony, Lord Stanley's Despatch of 1859 reinforces Wood's policy and establishes firmly the requisite structure for overseeing education and related policy at the provincial level.

The "Beautiful Tree"

It has often been held against Macaulay that his educational policy resulted in the demise of native educational systems. Indeed, this is the substance of the charge made by the Mahatma in his lecture at Chatham House (London, 10.10.1931):

> …India is more illiterate than it was fifty or a hundred years ago, and so is Burma, because the British administrators, when they came to India, instead of taking hold of things as they were, began to root them out. They scratched the soil and began to look at the root, and left the root like that, and the beautiful tree perished.

Myths have a compelling appeal, and soon the myth of the "beautiful tree" found willing adherents, eager to graft on to it engineering and engineering education in India that obtained prior to colonial rule. Scholars like Dharampal have documented Indian technology and agriculture on the ascendant till mid-eighteenth century, not to speak of an attendant comprehensive system of education embracing the bulk of its youth, however informal its structure (Dharampal 2000, p. 10). The sustained depletion of India's economy through an insidious system of taxation, the erosion of its social and cultural fabric by laying the axe at the root of its education system, in short the uprooting of indigenous wisdom by the scheming ingenuity of its colonial masters form the stuff of much colonial and post-colonial discourse, fuelled no doubt in part by professional malcontents eager to reclaim a romanticized past. It has to be conceded though that Dharampal's investigation of Indian science and technology in the eighteenth century is a special pleading for revisiting the past and its embedded value systems and to reconstruct self and society in that light in order to eschew the pitfalls of blind westernization (Dharampal 2000, pp. 13–14). Further, it cannot be denied that, for example, technical training institutions were set up largely to train middle level technicians for maintenance of public works and for military purposes. It may be argued that British intent was not to develop intrinsic human resources in India, yet by the early twentieth century through an osmotic effect, there is considerable Indian presence in the top echelons of the civil service and in academic establishments. Bhaskaran's trenchant observation merits, therefore, earnest consideration: "It is a popular superstition, impossible to eradicate, that our educational system was devised to produce and only turned out inferior employees of government and commercial offices. On the contrary it has produced in the past and is still turning out in large numbers, young men and women equipped to meet all the needs of a healthy society" (Bhaskaran 1967, p. 220).

The Industrial Imperative

In the third quarter of the eighteenth century, engineering education in India sought to address itself in the main to the technological deficit obtaining between local skills and the demands brought about by the industrial revolution. In addition, colonial rule, to acquire a firm grip on subject territory, required exhaustive information, so to speak, on the lie of the land. The Great Trigonometric Survey of 1818, for example, was prompted by this need and called for skilled experts (Arnold 2004, p. 25). Madras had established a Survey School as early as 1794. Following Wood's Despatch, the school at Madras was turned into a civil engineering school in 1858, and elevated in the following year to a civil engineering college. Likewise, civil engineering colleges came to be established in Poona (1854) and in Sibpur/Calcutta

(1856). Alongside Roorkee (1847) these locations describe geographically a quadrilateral, with each institution designed to serve, so to speak, its watershed. These institutions developed in stages; the college at Madras on shifting to the impressive redbrick building in suburban Guindy in 1920 came to be known as the Guindy College of Engineering, and forms today the influential core of the Anna University. The Poona Engineering Class and Mechanical School was renamed by 1911 as the College of Engineering, Pune, just as the college at Calcutta came to be known finally as the Bengal College of Engineering. (Renaming thus is not just an index of institutional advancement; it is equally reflective of the attempts to comprehend training in engineering skills within an academic frame.)

The construction of the Upper Ganges canal from 1842 for major irrigation works necessitated the establishment of a training school in Sahranpur, and soon it became in 1847 the College of Engineering on moving to nearby Roorkee. It was renamed in 1854 as the Thomason College of Civil Engineering in honor of its initiator James Thomason, the Lieutenant General of the North Western Provinces (Vir et al. 2011, p. 5). The transformation of the College to a university was accomplished soon after Independence (1949); laudably, it was inducted into the IIT league by an act of Parliament in the year 2001. Within a quarter century of its establishment in 1847, the institution at Roorkee had become more or less the role model for other engineering institutions in the country.

At Roorkee, programs of instruction were intended in the main for engineers (mostly military personnel), for assistant engineers (chiefly civilians for the Public Works Department) and last but not least for a large native class, who were educated as sub-overseers, sub-surveyors, estimators, and draftsmen (Medley 1873, p. 41). To go by Medley's first-hand account, Roorkee had also a "library, model room, and museums in the college, and an excellent press, whence a good many useful works have issued, chiefly relating to Indian engineering" (Medley 1873, pp. 41–42.). Indeed, the "Roorkee Treatise on Civil Engineering" bears eloquent testimony to native engineering skills. In fact, in acknowledgement of excellent mechanical skills obtaining among the native gunsmiths of Munger, the largest railway workshop in India was set up in 1862 at picturesque Jamalpur in Munger District, Bihar State. Jamalpur became home thus in 1905 to the first of many Centralized Training Institutes, namely the Indian Railways Institute of Mechanical and Electrical Engineering (IRIMEE). In sum, Roorkee and Jamalpur set the tone and tenor for engineering education, the ambitious collegiate education model and the more practical polytechnic model respectively.

The Victoria Jubilee Technical Institute may be said to be the precursor of the polytechnic model. Established in Bombay in 1887 to commemorate the Diamond Jubilee of Queen Victoria, it trained licentiates in electrical, mechanical, and textile engineering and technology (Sen 1989, p. 227). The Indian Education Commission of 1882 under the stewardship of Sir William Hunter made a series of excellent recommendations to improve technical education. Rather than yoke technical education to the colonial imperative, Sir William intended to forge an efficient industrial society in India by a concerted development of human resources. Understandably, he met with little success.

Milestones on the Path to Nationhood

All the same, with rising nationalist ardor, private initiative, and government support, the number of higher technical institutions in India too rose from 5 in 1919 to 21 by 1939; likewise the number of diploma schools increased from 8 to 23. Several leading institutions emerge during India's struggle for independence, notably: Institute of Technology of the Benaras Hindu University (1919, now an IIT), Harcourt Butler Technological Institute, Kanpur (1920), Indian School of Mines, Dhanbad (1926), Maclagan College of Engineering, Lahore (1930), University Department of Chemical Technology, Mumbai (1934), Engineering College at the Aligarh Muslim University (1935), Delhi Polytechnic (1941), Laxminarayan Institute of Technology, Nagpur (1943), Alagappa Chettiar College of Technology, Guindy (1944), etc., (Vir et al. 2011, pp. 4, 7).

Other scientific developments run more or less parallel to the foundation of these institutions, leading to the emergence of an Indian scientific community in earnest dialogue with its western counterparts from 1890 onwards. Publications like the *Imperial Gazetteer* documenting every aspect of India ranging from anthropology to zoology, professional associations and guilds, learned bodies and academic societies like the Bengal Medical Association (1885), Indian Association for the Cultivation of Science (1876), Indian Medical Congress (1894), Indian Science Congress Association (1914), Indian Institution of Engineers (1920), privately endowed research institutions like the Tata Institute of Science (1909, now: Indian Institute of Science), numerous government funded research establishments like the Indian Agricultural Research Institute (1905) at Pusa, the Central Research Institute (1906) at Kasauli etc., – all contribute significantly to the growth of a scientific community. The Imperial Civil Service and a host of similar institutions like the Indian Educational Service provide the solid administrative ballast. Research too gets a boost with the setting up in 1911 of the Indian Research Fund Association into which government funds and private donations were channeled (Arnold 2004, p. 144). Nevertheless, post-graduate education and research languished for the most part, and many Indian scholars went abroad for higher studies.

The British Nobel laureate Sir Archibald Vivian Hill was commissioned by the Viceroy's Council to report on the state of scientific and industrial research in India as part of a post-war reconstruction and reorganization plan. The report (1944) while praising India's scientific community, held that the war "had left India's scientists 'sorely cut off … from intellectual contacts with the rest of the world"; consequently, the scientific and technical resources of India had "not been utilized, or developed for war purposes to anything like the same degree as those of the other major countries" (Arnold 2004, pp. 196–197). Hill's report underscored also the need to give lead and direction to research through greater central coordination. This suggestion resulted ultimately in the strengthening of the apex body, the Council of Scientific and Industrial Research (est. 1942) under the direction of the eminent scientist Shanti Swarup Bhatnagar, especially in the post-Independence era.

India's Tryst with Destiny

It is not well known that the Hill report provided the platform for the establishment of the IITs along the lines of the MIT. It was Sir Nalini Ranjan Sarkar, Member of the Viceroy's Executive Council (Dept. of Education, Health and Lands) who took the cue from this report. He headed the 23 member committee set up in 1945 on the advice of Sir Ardeshir Dalal (Member-in-Charge of Planning and Development of the Viceroy's Executive Council) to go into the need for new institutes of technology to produce adequate technical manpower for the development of post-war India. Sir Ardeshir had in fact on his return from the USA in 1944 spoken of an "Indian MIT", spurring thus the imagination of policy-makers in India (Vir et al. 2011, p. 11). The Sarkar Committee in its interim draft of February 1946 recommended the establishment of four higher technical institutions along the pattern of the MIT, one for each of the major geographical regions.

In a notable departure from staid university fare, the Sarkar Committee emphasized the need for blending scientific training with a broad human outlook and recommended the inclusion of subjects like industrial administration, economics, mathematics, statistics, chemistry and physics. Further, it laid heavy emphasis on workshop and laboratory training. Teachers were to be allowed to have consultancy and research besides adequate leave to go back to the industry for keeping up to date with developments (Vir et al. 2011, pp. 13–14).

Soon after Independence, these recommendations found favor with the visionary ideas of India's first Prime Minister Jawaharlal Nehru. In stark contrast to Gandhi's plea for technology "cut to size" in keeping with simple needs of an India of villages, Nehru's call for the dynamic industrialization of India rested on the plank of heavy industries, public sector investment, nationalization of basic infrastructure and a planned economy. The compelling need for higher technical institutions was recognized right away, and the Eastern Higher Technical Institute was set up in May 1950, initially at Calcutta, and later renamed in November 1950 as Indian Institute of Technology Kharagpur, located strategically not far from Calcutta and its heavily industrialized hinterland. An Act of Parliament declared it in 1956 to be an Institute of National Importance (INI) and gave it autonomous status.

Other IITs followed soon in its wake: Bombay (1958), Kanpur (1959), Madras (1959); besides, the College of Engineering Delhi is converted into an IIT in 1961, the same year in which all IITs are declared by an Act of Parliament to be institutes of national importance. The purpose of such an act is to invest these institutions with a great measure of autonomy in charting their course. The academic credibility and international standing of these institutions owe much to this self-regulatory structure. A certain amount of internationalization took place in the early phase of institution building, with Government of India inviting developed countries to assist in the setting up of the IITs. American initiative came thus to IIT Kanpur, while IIT Madras became the largest recipient of German educational development aid. This helped the institutions to keep abreast of international academic developments. Besides, residential campuses almost the size of small townships, contribute by way of concentration of students and staff to the professionalization of the disciplines. Also, industry based projects and summer internships played a decisive role in the making of the young engineer.

The careful selection of higher secondary school leavers by an exacting nationwide Joint Entrance Examination (JEE) has played a significant role too in nurturing the IITs as institutions of international excellence, reflected by the very high proportion of students of the Bachelor of Technology program leaving mostly for American universities and highly paid jobs. Recent criticism that the JEE despite its stiff acceptance rate (top 2 % out of roughly 400,000 candidates) has become an avenue rather for numerates than literates has brought about significant changes from this year (2013), with a two-stage examination process in place. The JEE Main Examination subsumes now the entrance examinations held earlier severally by the numerous engineering institutions at the federal and state levels, while the JEE Advanced Examination poses the sterner challenge of entry into the IITs. Even as this promises improvement in the quality of undergraduate material, major concerns still remain about the quality of research at the IITs, not to speak of other engineering institutions.

State of Research

The need as well as scope for research was initially circumscribed by the limited objectives set out by the colonial educationists; further, the early universities were of an affiliating nature and did little to promote research. In fact, it was nationalist sentiment surrounding the establishment of the Tata Institute (1909) or the BHU (1915) that gave slight impetus to research (Saha and Ghosh 2011, p. 111). After Independence, the IITs have played a significant role in vitalizing research by meshing it with teaching; success at the Graduate Aptitude Test in Engineering (GATE) has become the standard entry ticket for public funded post-graduate education and research India wide. As part of Quality Improvement Programs (QIP) the IITs have encouraged teachers at engineering colleges to enroll for doctoral research; in addition to part-time doctoral positions for the industry, the IITs have had numerous tailor-made post-graduate courses for the public sector industries and the military establishment. Industrial consultancy and sponsored research have stayed the course at the older IITs, with much funding coming initially from government agencies, public sector undertakings and defense laboratories. Of late, the IITs have also put in place a reasonably well-funded system of post-doctoral fellowships. Nevertheless, scholars like Sen (1989, p. 247), Saha and Ghosh (2011, pp. 111–112), and Subbarao (2013, p. 64) have not hesitated to point out the inherent infirmities in research development. Natarajan has listed some of the persistent problems: research positions go often to the rejects of the job market; state universities find it hard to modernize infrastructure; much research is of the incremental variety, more theoretical than practical (cf. Saha and Ghosh 2011, p. 112).

It may also be said that tardy progress on the research front was initially the result of ill-defined policies and the failure to scale up institutions suitably for the purpose for want of funds. India's initial success with the First Five Year Plan (1951–56) led planners to accept more or less the Soviet style of planned economy. More ambitious 5-year plans came at a price though (Rothermund 1993, p. 130). The consensus among planners that industrialization alone held the key to the economy led to the establishment of capital-intensive public sector industries, low on productivity and high on employment. Curbs on private enterprise by the notorious "permit-license-quota" regime and import substitution measures, while engendering a protectionist market for the new industries, did little to encourage research other than attempts at reinventing the wheel.

Periodic performance audit at the IITs did much to address institutional shortcomings; for the first time in 1983 the Nayudamma Committee, chaired by Dr Yelavarthy Nayudamma, Director-General of the CSIR, initiated a comprehensive review of all IITs. Its findings, published 1986, are directed at reinforcing institute-industry partnership and at dedicated research for uplifting the living standards of India's vast rural hinterland. More importantly, the Committee sought to liberate research from the maze of obsolescence, both in terms of men and material, of old-fashioned bureaucracy and outmoded equipment (Vir et al. 2011, p. 121).

The Growth Story

Unwittingly, these recommendations came at a time when the collapse of the Soviet bloc was just around the corner and about to trigger off untrammeled globalization and a free market economy. Dwindling foreign exchange reserves compelled India in 1990 to depart from its populist socialist stance and to embrace willy-nilly liberal market values. The changes in its wake are phenomenal. Within a span of two decades, India has become an economic powerhouse, indeed a Prometheus unchained. India dominates today the IT and Software sector, Indian industry has entered into major joint ventures and mergers with multi-national concerns, companies like the Tatas today have a sizeable global reach, a state like Tamil Nadu, for instance, has become the major hub of the automotive manufacturing sector; besides, massive infrastructural investment in transport and communication has transformed the economy completely.

The telling impact of liberal reforms on the education sector can be hardly overlooked. Students have come to realize increasingly that good education alone can secure for them a professional future. For example, in recent years, 150,000 Indian students alone have invested over $2 billion on education overseas. [In comparison, central and state governments together invest annually roughly $3.7 billion in higher education (Panagariya 2008, p. 432).] From 157 engineering institutions at the start of the 80s, India now has over 3,500 engineering colleges and over 1,750,000 engineering students (CABE annual report,[1] 2012–2013). The booming economy has also in part marginally reversed the earlier trend of Indian students and researchers seeking their fortunes abroad, especially in the United States, not to speak of many Indian scholars settled there returning to their homeland and to jobs in many universities and industrial establishments. [From 1985 to 2000, Indian students earned more than 13,000 science and engineering doctoral degrees at U.S. universities, mainly in engineering and physical and biological sciences. They also earned by far the largest number of U.S. doctoral degrees awarded to any foreign group in computer and information sciences. Among IIT alumni alone, 25,000 are thought to be working or studying in the United States (Clark 2007, p. 9).]

The economic unshackling of India has converged somewhat fortuitously with a major revolution in telecommunications and a burgeoning IT industry with massive investments from the private sector, an industry whose potential was little recognized at first, thus eluding luckily stern bureaucratic scrutiny and likely snares. By the turn of the millennium, it had become abundantly clear that liberal reforms had to be backed by massive infrastructure and human resources development. In particular, the educational sector required urgent attention, more so because of the imperative to cash in on the so-called demographic dividend, the 70 % of population aged below 30. Besides, the cyber era and the influx of newer and newer technologies had set in train profound socio-economic, cultural and political transformations. One may indeed speak legitimately of Indian society in a state of complete ferment.

Given, however, the very nature of social dynamics, it is open to question whether academic education can ever manage to keep pace with social change, let alone anticipate it. In addition, universities have had to accommodate within the academic fold the rapid spread of emerging technologies, setting up new departments, research facilities and recruiting experts. In India, all major institutions charged with overseeing higher education have responded impressively to these new challenges. Education being a concurrent subject (cf. Schedule VII, Constitution of India), both the centre and the 29 states are equally responsible for the care of education at all levels. So, in 2002, upon the recommendation of the Mashelkar Committee, the centre made bold to convert all the Regional Engineering Colleges, established originally to satisfy regional aspirations and manpower needs between 1956 and 1960, into the National Institutes of Technology (NITs). Today there are 20 NITs, all declared as institutions of national importance, functioning with a great deal of autonomy and central funding, much on the model of the IITs, though under a different Act.

The liberating impact of this move is reflected in the vastly improved quality of education and research besides placement record. The IITs too have witnessed a decisive phase of expansion, with eight new IITs being set up to meet the growing challenges. The expansion of the Indian Institutes of Management (IIMs), the setting up of the Indian Institutes of Science Education and Research (IISER), proposals to upgrade some of the older technical institutions of repute (like the

[1] Central Advisory Board of Education, Ministry of Human Resource Development, Government of India.

Bengal College of Engineering Sibpur) into Indian Institutes of Engineering Science and Technology (IIEST) or the recent bid to expand the network of Indian Institutes of Information Technology (IIIT) through public-private partnership – all point to the complementary array of institutions needed to buttress technical education. The latest statistics set out in the appendix detail the institutions under the dispensation of the Ministry of Human Resources Development.

Private Enterprise

Yet, it is the private sector that has contributed largely to the growth of educational institutions in the last two decades, trying to match the staggering growth of the economy with a phase of near breathless expansion. Unlike the much older, benevolent private institutions, say the Birla Institute of Technology and Science Pilani or the A.C. College of Technology Madras, with undisputed academic credentials, a large number of the newer private establishments (self-financing institutions) was set up largely, often with political patronage, to bridge an ever-widening market gap (Varshney 2006, p. 3). To review the work of the prime advisory and regulatory body, the All India Council of Technical Education (est. 1945) in the light of the new situation, government set up the U.R. Rao Committee in 2002. Its report reviewed all engineering disciplines, architecture and town planning, the applied arts, hotel management, business management and pharmacy. In the main, it called for restructuring the AICTE to meet the challenges of globalization. It levels sharp criticism at the unregulated growth of private engineering colleges, their abysmal infrastructure, weak faculty resources, exorbitant fees and lack of research facilities. The unbridled growth of private colleges had led to several distortions, notably: (1) regional disparities on account of overcrowding of colleges in select regions to the neglect of other areas, and consequent oversupply in some markets and shortfalls elsewhere (2) the graduate growth rate far exceeded the economy's growth rate (3) poor standards make for unemployability, thus accentuating unemployment rather oddly in a market facing serious shortage of skilled manpower (4) manifestly, little effort had been made to understand the manpower needs of the industry and to offer tailor-made courses for the purpose.

NBA and the Washington Accord

Above all, the Rao report calls upon the National Board of Accreditation (est. 1987), an autonomous wing of the AICTE, to tighten up its lax institutional and program accreditation procedures, and to bring every institution under its scrutiny. In sum, the Rao Committee report "has pointed out, the AICTE needs to focus on ensuring that its standards are met at already existing institutions, new institutions are opened in areas that need them, substandard institutions are closed and that faculty shortages are reversed by investing in postgraduate education and encouraging talented students to remain in India to pursue careers in academia" (Clark 2007, p. 9). Uniform accreditation of over 3,000 institutions is a daunting task, and the NBA is yet to become a full signatory to the Washington Accord. The projected roadmap to full status in June 2014 is paved with good intentions, but ground realities suggest a long haul. In the short run, a two-tiered accreditation framework with Tier I status for top-rated Indian institutions like the IITs is more likely to set in train the entire process of quality assurance, continuous improvement, training of university coordinators and program administrators, and training of faculty for outcomes-based accreditation (cf. NBA website).[2]

Reform and Self-Renewal

In the last two decades, the IITs have witnessed large-scale expansion, with new IITs being opened in underserved areas of the country. The imperatives of globalization have made the IITs address the need to raise research and development to internationally competitive levels. The Rama Rao Committee set up in 2004 developed a roadmap for the future, based firmly on the maxim that "excellence is a journey and not a destination". It advocated induction of foreign nationals as faculty besides joint appointments with industry. It also encouraged giving research incentives and the induction of bright B.Tech students into challenging Ph.D. programs; it wanted to enrich the science and humanities component of the undergraduate program besides promoting design and business centric projects. It wanted the IITs to profile their research and innovation through better IP management (cf. Kakodkar Report 2011, p. 15).

Building upon the Rama Rao report and striking an even bolder approach to a brave new future is the report of the Kakodkar Committee tabled in April 2011, and predicated upon "our national development aspirations, growing economy with inclusive participation, creating opportunities for our youth and building our competitiveness in the emerging knowledge-driven global economy". It is based upon the firm conviction that the "IITs are by far the only institutions, which can lead this process on a scale commensurate with the needs of our country". At the same time, it notes that "with only 7,500 undergraduate (UG) and less than 1,000 Ph.D. students graduating every year, the output of the IITs is inadequate for the future". Kakodkar observes ruefully: "Clearly the world has passed us by. If India has to be among the three largest economies of the world, the IIT system has to grow several folds in terms of research output, the number of PhDs and student graduation." To achieve this aim, the IITs have to be more accessible to a greater number of talented Indians. And more importantly, transparent as well as greater representative governance are indispensable: "The IITs should have standards benchmarked against the best universities around the world. One of the essential ingredients for this is a good

[2] As this text goes into press, it may be noted that India has become a signatory to the Washington Accord as of June 15th, 2014.

governance system with an independent and fully empowered Board with representation from key constituents such as scientific establishment, industry, alumni, faculty and Government." In practice, the key recommendations read thus (Kakodkar 2011, pp. 162–163):

- Make IITs the Primary Research Institutes, with a focus on high quality frontier research and technology development within the Indian context.
- Scale up Ph.D. students from less than 1,000 Ph.D. graduates per year today to 10,000 Ph.D. graduates by 2020–25 from about 20 IITs (15 existing IITs plus 5 new to be set up over the next several years in states where there are no IITs).
- Scaling Ph.D. scholars' admissions to include enabling bright UGs being admitted for Ph.D. at the end of their third year, teachers from other institutes joining for Ph.D. and significant numbers from industry joining sponsored/part-time Ph.D. program. It is strongly recommended that a fellowship scheme covering all categories of PhD students is in place.
- The faculty: student ratio is 1:10; while the UG: PG ratio is close to 1:1.
- Each IIT should aim to acquire technology leadership in at least 3–4 areas.
- Research groups in one or more IITs to take up large projects together to address major national challenges
- Set up research parks at each of the IITs similar to the IIT-Madras Research Park.

While making research integral to the IITs, the Committee has also recommended an Executive M.Tech program for about 10,000 working professionals from industry through live video classes to enhance the knowledge base in the industries.

In keeping with the focus on innovation, the Ministry of Human Resources Development (MHRD) has also introduced in May 2012 the "Universities for Research and Innovation" Bill in Parliament with the aim of creating institutions "recognized universally for their quality in teaching, learning and research" (CABE annual report 2012–13, p. 13).

In a more recent development, alarmed by the fall in global rankings of premier engineering institutions, the MHRD has announced independent third-party reviews of all the 15 IITs (Indian Express 2013a, p. 6). Parameters for the review include among other things: global character of the institution (in terms of international student enrollment, visiting foreign faculty and courses with international participation), internationalization (in terms of publication and citation index), alumni engagement quotient, adequacy of facilities and teaching, contribution to national development goals (NDGs), transparence in governance structures and, last but not least, student and faculty diversity in terms of gender equity.

Much of the scaffolding for these bold measures and blueprints has come from the pivotal role of the National Knowledge Commission (est. 2005 with Sam Pitroda as chairperson) in fortifying higher education. Primarily, it has sought to develop appropriate institutional frameworks (1) to strengthen the education system, promote domestic research and innovation, facilitate knowledge application in sectors like health, agriculture, and industry (2) leverage information and communication technologies to enhance governance and improve connectivity (National Knowledge Commission, March 2008).

The advances made in information and communication technology hold great promise for distance education, enhancing in particular the reach and quality of engineering education, offsetting in a way acute shortage of faculty and at times woeful quality of instruction. The National Program on Technology Enhanced Learning (NPTEL) is an initiative by the seven IITs (IIT Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and Indian Institute of Science (IISc) for developing curriculum-specific video and web based course contents in engineering, sciences and the humanities (Natarajan et al. 2009, pp. 71–77). Spurred by the initial success and encouraged by the MOOCO (massive open online courses) floated by Western campuses, in a most recent initiative, seven IITs, the IT industry and NASSCOM are set to revolutionize higher technical education in India by offering free online courses (Indian Express Editorial 2013b).

Polytechnics

Free online learning supplementing the curricular offerings of India's dedicated television education network "Gyan Darshan" (with telecasts in English and regional languages) is bound to make a qualitative impact on the middle-level technical education sector too. From about 50 polytechnics at the time of Independence, India now has around 1,300 training institutions. But the irresistible appeal of entering the boardroom has held out against the enticements of the shop floor. India thus produces today more engineering degree graduates than diploma holders. This unhealthy trend is in need of urgent remedy, for the industry faces a serious shortfall of skilled technicians. Over the years, clear improvements to the quality of polytechnic education (cf. G.R. Damodaran Committee 1970) have been made, the curriculum revised and fine-tuned to meet industry requirements, and sandwich programs devised for lateral entry to university courses. Today, however, the emergence of a large service sector, which hinges considerably on technology applications, has necessitated a relook at the scope of polytechnic education. The new curriculum sports a considerable IT component; besides, more diploma courses, especially in soft skills, make the polytechnics attractive for women students. More significantly, the MHRD has proposed a Scheme of Community Development through Polytechnics (CDTP) and their extension centers. This aims at "providing non-formal, short-term, employment oriented skill development programs, through AICTE approved Polytechnics, to various sections of the community, particularly the rural, unorganized & disadvantaged sections of the society, to enable them to obtain gainful self/wage employment". In a significant reinforcement of the polytechnic system, the MHRD has decided recently to set up 200 Community Colleges in states and union territories in order to redress the gross mismatch between supply and demand for skilled workers. The Community Colleges are being planned within the overall framework of National Vocational Education Qualification Frameworks (NVEQF) (CABE annual report 2012–13, p. 17).

Women in Engineering

In the last couple of decades, women have taken increasingly to undergraduate engineering programs, and the industry has paid recognition to their excellence (Parikh et al. 2004, pp. 193–201). From 124,606 women enrolled for engineering subjects in 2000–2001, the number has risen to 276,806 in 2009–2010 according to a report of the University Grants Commission of India (UGC). The most recent upgrading of the Indira Gandhi Institute of Technology into the Indira Gandhi Delhi Technical University for Women (IGDTUW) in May 2013, has been prompted by the need to recognize women's aspirations and to empower them as engineers in accord with changing social trends and perceptions. This is in addition to the 14 exclusive women's engineering institutions, mostly in the private domain, and spread across various regions of the country, complementing several women's universities set up by many state governments over the last three decades and over 4,000 women's colleges, public and private. Significantly, women students constitute today 41 % of the total student enrollment in higher education.

The Uncharted Future

Academic organization and transmission of knowledge has to come to grips today with the global dimension of the new knowledge economy. In particular, technical education in India faces the twin challenge of being internationally relevant and internally useful. While the application of technology to rural life offers much scope for research and innovation, it has become increasingly clear to scientists that the heady initial optimism of solving rural problems by technical intervention alone is hardly feasible. Problem solving has to take into account the received framework of tradition and experience. Likewise, the global reach of multi-nationals and industries today calls for training in foreign languages, and in social and cultural competence. In other words, policy makers are recognizing increasingly the indispensable role of the humanities and social sciences, disciplines that were studiously ignored earlier, if not grudgingly acknowledged and conveniently consigned to the so-called service sector. In many engineering institutions, it has now become standard practice to fling fresh undergraduates in at the deep end of the pool in a bid to expose them to the requirements of engineering design and innovation. With marginal mentoring and with little theoretic input either from the social sciences or from the engineering disciplines, raw undergraduates have been compelled to reflect on product design, technology assessment and attendant lifestyle changes. This near autodidactic course component – reminiscent of the WPI and CDIO models – has in considerable measure reinstated, if not rehabilitated, the humanities and the social sciences in the engineering curriculum. Indeed, some of the IITs have been introducing full-fledged graduate studies programs in the arts and social sciences in a move to rediscover the true integrative power of knowledge in its diverse forms. Indeed this recent, not wholly unintended development may be the unforeseen prelude to improving the quality of human resources, to internationalizing education and to enabling academic mobility, reviews and solemn recommendations of committees notwithstanding. Besides, there is an urgent need to rejig the cluttered curriculum in keeping with current multi-disciplinary requirements of the emerging technologies, discarding outdated topics in favor of a unified common core structured around a combination of solid and fluid mechanics, electro-magnetic fields, heat transfer, and digital signal processing. Such a move may also result in freeing up a little more learning time for an imaginative encounter with the humanities.

Toward the end of our survey, it may not be out of place altogether to point to Panagariya's puzzler. He asks pertinently how a "dysfunctional system such as the one India currently has can produce so many students able to compete with the best in the world. Such students come not merely out of the top, well-run institutions outside the ambit of the UGC, such as the IITs and IIMs, but also lesser universities and colleges" (Panagariya 2008, p. 443). To him, the answer to this paradox lies in the enduring intellectual tradition of India, the excellence of private schools, and the centralized testing procedures of the universities. Privileged access to schools instructing in the English medium tilts no doubt the balance in favor of a small, elite band, if the recent report of most seats in the IITs going to major metropolises is any indication. Nevertheless, the picture is one of acute contrasts: on the one hand, world-class institutions of the caliber of the IITs with their unmistakable quest for excellence, and on the other the continuing failure to take adequate funding and reform to where it all matters, when it comes to improving demographic quality, namely primary education. Even today, the myth of the "Beautiful Tree" has a haunting ring to it; like the plum tree in Brecht's eponymous poem, it cannot be recognized by the fruit, for it bears none; yet, you can tell it by the leaf.

Appendix

Select Statistics

Table 5.1 Number of colleges, universities, and students

Year	Colleges	Universities	Students (million)
1857–58	27	3	0.00025
1947–48	496	20	0.2
1950–51	578	28	0.2
1960–61	1819	45	0.6
1970–71	3,277	93	2.0
1980–81	4,577	123	2.8
1990–91	6,627	184	4.4
2001–02	11,146	272	8.8
2005–06	17,625	335	10.5

Sources: Central Advisory Board of Education (2005, table 5.1); Government of India (2005–06b, chap. 10), see Panagariya (2008, p. 441)

Table 5.2 Number of institutions and enrolment

Number of institutions/enrolment	2010–11	2011–12
Universities	523	574
Colleges	33,023	35,539
AICTE approved technical institutions	11,809	13,507
Distance teaching universities/institutions	200[a]	200[a]
Enrolment in the universities and colleges (in millions)	16.975	20.327
Enrolment in open distance learning (ODL) system (in millions)	3.745[b]	3.856[b]
Enrolment in post school diploma/PG diploma (in millions)	1.856[b]	23.02[b]
Intake in AICTE approved technical programmes (in millions)	2.615	3.014

Source: CABE annual report 2012–2013, p. 56. UGC annual report 2011-12/AICTE annual report 2011–12/Statistics of higher and technical education 2009–10 (Provisional)
[a]Repeated at the level of 2009–10 as per Prof. N.R. Madhava Menon report of committee to suggest measures to regulate the standards of education being imparted through distance mode
[b]Estimated

Table 5.3 Programs, number of institutes, and intake

S. no.	Program	No of institutes	Intake
01	Engineering	3,495	1,761,976
02	Management	2,450	385,008
03	Master of computer application	1,241	100,700
04	Pharmacy	1,145	121,652
05	Architecture	126	5,996
06	Hotel management & catering technology	105	8,401

Source: CABE annual report 2012–2013, p. 62

Table 5.4 Major centrally funded institutions

(i) Central universities	44[a]
(ii) Deemed university	130
(iii) Technical institutions	16 – Indian Institutes of Technology (IITs) 30 – National Institutes of Technology (NIT)
(iv) Management institutions	13 – Indian Institutes of Management
(v) Information technology institutions	4 – Indian Institutes of Information Technology (IIIT)
(vi) Science & research councils	5 – Indian Institutes of Science Education and Research (IISER)
	1 – Indian Institute of Science (IISc)
(vii) Planning & architecture institutions	3 – School of Planning & Architecture
(viii) Training institutions	4 – National Institutes of Technical Teachers' Training & Research (NITTTR)
(ix) Planning & consultancy institutions	1 – NUEPA & 1 – EdCIL
(x) Area/sector specific institutions	7 [1-Indian School of Mines (ISM), Dhanbad; 1-Sant Longowal Institute of Engineering and Technology; 1-North Eastern Regional Institute of Science & Technology (NERIST), Itanagar; 1-Central Institute of Technology (CIT), Kokrajhar; 2-National Institute of Industrial Engineering (NITIE), Mumbai and National Institute of Foundary & Forge Technology (NIFFT), 1-Ghani Khan Choudhury Institute of Engineering & Technology (GKCIET), Malda, West Bengal
(xi) Institutions of national importance	33[b] [7 IITs, 20 NITs, 5 Universities and 1-Hindi Institution]

Source: CABE annual report 2012–13, p. 74
[a]Of which, 39 are being given maintenance and development grant by MHRD through UGC. The IGNOU, New Delhi, the Central Agricultural University, Imphal and the Indian Maritime University, Chennai are being funded by MHRD, Ministry of Agriculture and the Ministry of Shipping and Transport respectively. The funding for South Asian and Nalanda Universities is being made by the Ministry of External Affairs
[b]These institutions are included amongst the existing IITs/NITs/Universities/Institutions

Table 5.5 Women's enrollment: rise across streams

Stream	2009–10	Change (%)	2000–01
Arts	2,772,580	62	1,711,487
Science	655,257	72	1,129,255
Commerce/management	545,712	68	915,719
Engineering and tech.	124,606	122	276,806
Medicine	107,177	89	202,803
Law	89,256	33	67,196
Education	180,771	223	55,907
Agriculture	15,253	74	8,769
Vet. sciences	4,519	29	3,511
Others	62,140	118	28,499
Total	5,649,102	70	3,325,927

Source: UGC annual report 2010–11, p. 52, table 2.4; here: from: Kasturi (2011)

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[3]**Note**: *All Annual Reports of the Central Advisory Board of Education (CABE) besides most reports of committees constituted by the MHRD can be had at:* http://mhrd.gov.in.

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Balasundaram Subramanian B.Sc. in Chemistry followed by an M.A. and Ph.D. in German Studies from the Karnatak University Dharwad, India. Presently, he heads the School of Humanities & Social Sciences at the newly established Indian Institute of Technology Mandi in the Himalayan State of Himachal Pradesh in India and is responsible for designing the humanities curriculum of the undergraduate program in the engineering disciplines. Prior to this assignment, he was Professor of German Studies at the Indian Institute of Technology Madras (till 2007) and also Professor of German Studies at the Jawaharlal Nehru University New Delhi (from 2008 till 2011). Publications notably on Rilke, Goethe and Weimar Classicism.