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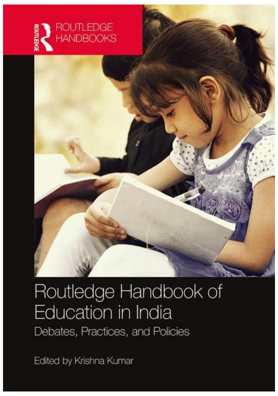

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Krishna Kumar

The making of India as an engineering society

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Part III
Training for professions

In this part, the readers will find three chapters that discuss professional training in three different fields. These three are hardly representative of the vast area of higher professional education in India. All they do is introduce you to the nature of the development that has taken place in this sector of higher education and also the nature of the problems and challenges that professional education faces. Although each field of professional education faces challenges that are specific to it, the three chapters included in this section might give a glimpse of some general or theoretical problems. These have to do with knowledge and its active application in the course of a professional career or life. A professional career implies specialised learning, which is used for a public purpose. The training for such a career involves learning of a kind that might include the experience of using it. Thus, professional education can be distinguished from higher education of a general kind which aims at imparting knowledge without necessarily focusing on the skill or a set of skills required to use such knowledge for a career devoted to providing a service based on such skill.

Professional education in law, engineering, and medicine started during the colonial period. The first chapter in this section concerns engineering, and it demonstrates the importance of taking into account colonisation as a factor for shaping the character of engineering education and its problems or challenges. We are not talking about the colonial legacy, a frequently used term in the context of education, but rather a wider inheritance that shapes the perception of knowledge and the role its application might play in addressing the problems of human life. In his chapter, Milind Sohoni first explains the development of engineering education in the West, especially the USA, in order to argue that the idea and image of a professionally qualified engineer there is embedded in socio-economic needs and expectations. He contrasts this case with that of India, where the engineer learns advanced knowledge in order to receive a high qualification, not in order to respond to or address any real and immediate needs. Thus, the engineering curriculum, even of apex institutions, fails to equip the young engineer to notice the problems that his knowledge and skill might solve in the Indian milieu, urban or rural. These characteristics of engineering education may be similar to other areas of professional education. A general point can be made about the social status that education leading to a medical, engineering, or architecture degree offers to its recipient. If Sohoni's analysis is extended, we can say that the status associated with professional qualification in an area like engineering may be the

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driving force behind the continued popularity of these courses, rather than the knowledge and skill they impart. A wider phenomenon of the 'commonisation' of the engineering degree over the recent period may also be linked to this. This phenomenon has resulted in a glut of private institutions and a decline of enrolment in pure science courses at higher levels, noticed by Shobhit Mahajan earlier in this volume.

Training of teachers is another area of professional education examined in this part. Concern for the quality of teaching has been a consistent theme in public documents and scholarly literature on education, and the expression of this concern has become shriller over recent years, with the recent expansion of the system and an increase in the number of children enrolled at all levels. Demand for trained teachers has mounted, and the state has responded to this demand by encouraging private initiatives in establishing and running teacher-training institutions. Over 80 per cent of all institutions offering training degrees today are private. The apex regulatory body, the National Council of Teacher Education (NCTE) has recently launched a series of reforms in various courses, including the Bachelor of Education (BEd) course that qualifies a teacher to be appointed at a secondary school. In her chapter in this section, Latika Gupta examines the established structure of the BEd curriculum, focusing on the division between 'theory' and 'practice'. She also presents an analytical description of the ethos of a teacher-training institution. An obsessive emphasis on methods of teaching, coupled with the inability to link educational theory with subject knowledge, is identified in this chapter as a key weakness of the BEd curriculum. The ethos accentuates the absence of academic depth of the course, reinforcing the influence of an unreformed school education system on the new generation of teachers.

Unlike engineering and teacher education, management education has no historical legacy as such. It is a relatively new area of professional education and it does not seem to suffer from financial constraints. Pankaj Chandra examines the growth of management education in India and the role it has played in providing specialised personnel to the expanding industrial establishment. This chapter brings out the strengths that institutional responsiveness to the needs of industry has imparted to the curriculum in apex institutions. It also points out how the state's attempt to regulate the sector has made it vulnerable to problems similar to other areas of professional education.

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10
The making of India as an engineering society

Milind Sohoni

Education, especially higher education, is perhaps the most direct intervention that a society may make in changing itself, and thus its design offers an effective formal tool for social transformation. Within that, engineering education is certainly privileged, since its very objective is to prepare agents of material change. The training of an engineer within a society offers a unique insight into what the society attributes as important as well as amenable to scientific or technological analysis, the nature of accumulation and transmission of material knowledge, and finally the effectiveness of the society in delivering material wellbeing to itself. It is within this broader connection with the material society that we explore engineering and scientific education.

Hence, it is important that we examine the massive problems of inequity and development in our society, at least partly as problems of design and conduct of higher education. In this chapter I look at the profession of engineering and of applied physical sciences in India and the system of training and research that supports it. The objective is to tease out its structural features, its social and cultural embedding, and, increasingly important, its linkages with global knowledge. In the first three section, I will (1) describe a mechanism of knowledge formation and delivery, (2) narrate a history of the evolution of this mechanism in the West, and (3) use the above two constructions to analyse the Indian system of engineering education, post-Independence, and its outcomes. I use the West as a reference, since it is one which is closest to us in organisation, and which has served as a role model, and yet which is antipodal in initial conditions and conduct. In a later section, I collect together various strands from the earlier parts and point out the central role of culture and of rigour in the trajectory of an engineering or scientific society. We will also look at the emerging global knowledge system and its key axioms as an example of a scarce and (culturally) hegemonic science. Finally, we propose a science and engineering system that is more likely to deliver development. In the final section I conclude by embedding the outcomes of our analysis into the broader question of the design of higher education, its political economy, and the role of the social sciences.

The meaning of a profession

Professional education, as opposed to a ‘liberal education’ such as in the humanities, social sciences, or the pure physical sciences, is by nature instrumental and embedded in society. It aims

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to produce agents (1) who satisfy an expressed demand for a particular service or social value and expect to be rewarded in money or in kind, and (2) who access a body of professional knowledge and yet tailor it to suit a particular situation. Inherent in the notion of a profession is an association or group of professionals, their body of professional knowledge, and, finally, a charter, i.e. a social recognition of the profession and the above transaction. The profession is then a mechanism organised as (1) a *paired vocabulary*: an external or social vocabulary in which problems or demands are specified, and an internal professional vocabulary in which knowledge is expressed and solutions are designed; (2) *a professional knowledge* and a system of translation which is *sound*, i.e. which is successful in meeting posed demands; (3) *a method of accumulation*, i.e. an epistemology which is *rigorous* – which maintains soundness and expands the profession. The translation from the external to the internal vocabulary may well be called analysis and design, while the reverse may be termed as synthesis or implementation.[1]

A simple example of a profession is football coaching, where, for example, the social vocabulary would be of scoring goals and executing popular manoeuvres, while the internal vocabulary may have theories of physical fitness and technique. The social charter of the profession is achieved through certification exams aligned with national and international sports associations. Note that the internal vocabulary of the professional may well be an interdisciplinary combination, e.g. in this case, of human physiology, ergonomics, and strategy.

Engineering is largely the profession of bringing about change in the material wellbeing of a society. It is concerned with the building of bridges and buses, shampoos and phones, various other gadgets, of provisioning services such as water supply and electricity, and also of goods and services sought by other industries, such as steel and shipping. As a profession, engineering is as old as history itself. Early engineers included shipbuilders, blacksmiths and smelters, lens-makers, and masons and other craftsmen and artisans. Their knowledge was largely situated within guilds and their practices, and entry into these guilds was frequently difficult. The modern engineer, however, is typically a university graduate and has access to a public body of professional knowledge.

Engineering in the West

Let us now quickly review the recent history of engineering in the West in terms of the mechanism that we have outlined above. It will serve to illustrate the various strands that have contributed to the evolution of the mechanism and also set up a framework for analysing Indian engineering.

Phase 1

Early organisation and transmission of engineering knowledge in the West was largely through two mechanisms, namely the guilds and the state machinery. Guilds were professional bodies of craftsmen organised around commercial production and services, e.g. for printing and stationery, leather-work, carriage-building, and apothecary. Entry into the guilds was managed through an elaborate apprenticeship protocol that was partly cultural and partly technical. The social embedding was frequently achieved by obtaining a royal charter, i.e. a monopoly on standards, regulation, and training of the particular activity within the royal domain. This charter was essential in maintaining the profession.

The second organisation of knowledge came from the engineering needs of the state; for example, in public works such as bridges and roads, in military engineering, and shipbuilding. This was organised around state departments, key contractors and companies, and their institutions of

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training. Civil engineering (i.e. the non-military part of the state agenda) was the first to achieve the public-access structure that is known today. The Institute of Civil Engineers was formed in England in 1818 and was itself preceded by the Society of Civil Engineers, founded in 1778. The institute began as a body of professional engineers and heads of building companies, which met regularly. It then transformed into a professional body with its own library and publications. By the late nineteenth century, it had evolved a curriculum and was also conducting certification examinations that were widely recognised. In fact, the Indian university is based on this tradition of certification on a recognised curriculum.

In France, the early 1800s saw the founding of the *grandes écoles* in various areas such as military engineering, shipbuilding, and bridges and roads. Similar progress was made in Germany as well as in the USA. The first degree/certificate in engineering in the USA was in civil engineering and was awarded in 1835 by the Rensselaer Polytechnic Institute, which was also the first purely technical university in the country. The need for professionals to run India's colonial administration led to the formation of the Thomason College at Rourkee in India in 1847. Though open to the public, it had separate programmes for Englishmen and for natives and its graduates were absorbed into the public works department of the colonial state.

There was a third knowledge tradition – the university. However, till the early eighteenth century, the European university was largely denominational and its training was in the classical traditions of metaphysics, philosophy, history, jurisprudence, and medicine. It was only in the eighteenth century that science entered the old university as a part of the philosophy of nature. Recognition of experimentation and theorisation as a method of science and engineering came much later.

Phase 2

The Industrial Revolution led to many innovations in engineering, and much of this happened outside the universities. In fact, one of the tasks of the scientific societies in Europe was to document and codify these inventions. With the advent of factories, and the capitalist mode of production, the producer no longer owned the means of production. Whence, the earlier role of the craftsman bifurcated into two distinct roles, namely the workman or tradesperson, and the professional engineer. The workman was to perform a fixed role of operating certain machines, while the engineer was to keep the machines and the factory in good order, and perhaps invent or adapt existing machines. In this connection, two important examples are the Mechanics Institute at Manchester, England, founded in 1824 jointly by the city and local industrialists, which later became the University of Manchester Institute of Science and Technology, and the Technical University at Dresden, Germany, in 1828. Both were non-denominational, open to the public, and were started to train existing workers in applied science and thus help them transcend their class and become engineer-inventors. This model of the technical university to prepare the engineer-inventor, as distinct from the workman, was replicated across Europe and led to many private and state-funded technical institutions.

In the USA, an important experiment in engineering education was the public land-grant university, which was funded and managed by individual states. These were large multidisciplinary public institutions founded around the 1860s, with the explicit agenda of knowledge provisioning for regional needs and preparing human resources for regional development. Agriculture, its mechanisation, management of natural resources, and urban and rural planning were important areas of applied research and training. Thus, these combined the cultural agenda of the older universities and yet provided for the 'extension' requirements of society. To this day, the Universities of Illinois, California, Minnesota, and others are important knowledge

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instruments in the hands of the states within the USA. In fact, the popularity of the American scientific fairs and other formal and informal extension activities led Oxford University to start its own version in the 1830s, called 'Continuing Education'. This was implemented as an outreach programme of public lectures in small towns on all aspects of knowledge and culture. American professional bodies started in the 1850s, with the American Society of Civil Engineering (ASCE) in 1850 and the American Society of Mechanical Engineers in 1880. These bodies devoted much energy to journals, standards, and curricula.

There was still much engineering and experimentation outside the university, and an active patent regime to protect inventions. A typical thread is the development of the external combustion engines, i.e. the steam engine of James Watt in 1788, the Stirling engine in 1818, and later the internal combustion engine of the 1860s, which eventually led to the modern car engine.

By this time, the scientific societies and the classical university had joined hands in the furtherance of the 'natural sciences'. This contributed many fresh ideas to engineering and to the economy. An important example is the discovery of electricity in scientific circles, and its uses in industry, e.g. in electroplating and telegraphy. The founding of the Institution of Electrical Engineers in 1871 in England marked the absorption of electricity and magnetism into professional academia as well as industry.

An important philosophical thread which emerged in this phase was the exploration into the role of science in the design of society, pioneered by Bacon and then later by Rosseau and Comte (see Scharf and Dusek 2014). Economic models of society, such as the fictional dog-and-goat island of Townsend, actually motivated Darwin to look for such islands in the natural world (Polanyi 1944). Many philosophers, such as Marx and Weber, and later Heidegger and Foucault (again see Scharf and Dusek 2014), have commented on the influence of technology on society, such as disenchantment, 'enframing' of nature and society by technology, and the creeping governmentality of personal and social interactions.

Phase 3

By the 1900s there was an effective convergence between the old university, the new technical university, industry, and the state. This was exemplified by the formation of the Imperial College of Science and Technology in London in 1907. Both science and technology entered into a new partnership, and so did theory and practice. Professional bodies had matured and served as a bridge between academia, industry, and state. They did this by publishing journals, through certification, curriculum design, and maintaining state-supported industrial standards, and therefore the charter. Research was conducted both in industry as well as at the research universities. For example, in Germany the Max Planck Institutes were founded in 1911 to extend the Humboldtian vision of the research university. This network of research institutions rested on the foundations of a large state-sponsored university system. As the civic infrastructure was put in place, the traditional 'civil' requirement of the state for engineers slowly declined, and by the 1960s it was the industry and the professional firms that hired the engineer and set the curricula. In 1958, MIT did away with the Sanitary Engineering Department and now, in 2017, the word 'sewage' does not appear in the *body of knowledge* document of the ASCE (ASCE 2008).

The engineer was now typically trained in a large, public, multidisciplinary university and his/her training was complemented by a 'liberal education' in the social sciences, humanities, and the physical sciences. The university was largely residential and provided a unique cultural experience and a common social understanding.

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There also emerged two paradigms of research. Foundational and disciplinary research in both the sciences and engineering was done by the university and this was largely in the public domain. On the other hand, industrial laboratories of large companies, which had now emerged, did proprietary research in applied areas. Much of the research in these laboratories was done by interdisciplinary teams of professionals from all disciplines of engineering, sciences, economics, and other social sciences. This eventually grew to what is now called Mode-II research, i.e. highly technological and fundamental research, with large investments and long gestation periods, and yet proprietary and profitable. This intruded upon the earlier Mode-I university-driven research of the early 1900s, which was publicly supported, in the public domain, and moderated and critiqued by peer groups (Nowotny *et al.* 2001).

Today, in the West, there is a clear and dominant paradigm of 'scientific engineering' in the modern engineering curricula and that is a belief in abstract models of phenomena and the use of mathematical techniques for analysis. This highly disciplinary and specialised approach was pioneered by American colleges in the 1960s and now dominates engineering curricula worldwide, right from the design of core subjects for first-year undergraduate students. It is also institutionalised by the way research is evaluated, and in the sites for applied research. Perhaps this viewpoint arose from the great success of 'deep science', e.g. theoretical physics in the early 1900s, and its connection with actual technological devices, e.g. relativity translating into nuclear energy, quantum mechanics into the transistor and other semiconductor devices.

Behind the disciplinary curriculum is also a corporatist belief that (1) the society is well served by the corporation; (2) it is also the correct location to operate and reward the interdisciplinary vocabulary of the engineering profession; and finally (3) the corporation is again the correct location to absorb the deeper disciplinary knowledge of the employee scientist-engineer and convert it into something useful. Thus, it is the corporation that generates social value and shares it with its employees.

This viewpoint has been challenged on two fronts. The first, which is still corporatist, views the modern engineer as a member of various interacting and interoperational teams who will design and test large engineering systems such as an aircraft engine. The disciplinary training fails to imbue in the student various interfacial skills of working within deadlines, designing around legacy black-box systems, the role of testing and standards, and the overall value of good practices. All of this, it is argued, must find a place in the training of the modern engineer.[2] The second criticism comes from the outside and points to the missing societal interface in professional training, and wants it unmediated by the corporation. This viewpoint, as followed by, e.g. Olin College, USA, sees designing for concrete users such as an urban cyclist as essential to its pedagogy. This is the entry point to teaching innovation as well as to framing broader normative concerns such as sustainability and global development.

On the whole, the progression in the profession of the engineer first as a guildsman, then as a state engineer, later as an engineer-inventor, and finally as a deep-science employee-engineer (i.e. 'the geek') has been an important ingredient in the social and material processes in the West. Moreover, the evolution of engineering into a curriculum within a public-access university was the amalgamation of several historical and cultural strands. This included the social churn arising from 'enlightenment' and the Industrial Revolution, and also numerous experiments in the definition of the university, e.g. the extension role or the technical university and the training of workmen. It was also shaped by a wide range of socio-economic and political agents, and a broad understanding within society on the role of science and technology in its transformation. Finally, the de-socialisation of the modern engineer in the West is a culmination of its current economic processes, and is not without its critics from within and without science and engineering.

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The outcomes

Let us connect this with the socio-economic and cultural trajectory of the West. Life expectancy increased from about 50 in 1830 to about 65 in 1940, and is now close to 80 (Roser 2015). Better engineering has contributed as much to this increase as the 'governmental' role of gathering data and putting it to use. Remarkably, having a theory for the price of prevention, i.e. the counter-factual, is a hallmark of the West and this led to many investments and innovations in engineering and medicine. In fact, these empirical systems also led to the emergence of the 'rational' bureaucrat and a revolution in governance. The basic needs of water, food, etc., and energy in the form of electricity, have long been met. Professional bodies remain strong and peer groups define the conduct of science and technology all over the world. Culturally, too, the university continues to be a strong influence on the conduct of the state and the market. It has contributed to a common social appreciation of the sciences and the arts and a social comprehension of the state. People of Western societies are remarkable in their broad understanding of a common rigour and causality, which in turn allows collective action and a view of the future as amenable to a shared design. Science and engineering in the West, behind its material facade of gadgets and factories, 'natural' theories, and 'physico-mathematical' laws of causality and conservation, remains a deeply cultural tradition.

Given our colonial past, and the material successes of the West, it is only natural that Western traditions of science and technology should serve as a role model for us in India.

Engineering in India

Let us now turn to India and take a brief look at its evolution as an engineering and scientific society. Persistence of medieval socio-economic and cultural arrangements alongside cultural and material upheaval caused by years of colonial rule was the backdrop against which India gained Independence. The 150 years prior to 1900 was also a period in which the country suffered major de-industrialisation and a significant loss in wages and numbers. The number of industrial workers, largely in cottage industries, came down by half to about 8 per cent of the population. In the second half of the period significant land was devoted to cash crops, namely cotton and indigo, which were used by the British as tribute. India was wracked by many famines, including the great famines of 1896 and 1943, which wiped out five million people each. The life expectancy actually fell from about 26 in the 1800s to 24 in 1900, and then rose to about 32 in 1947 (Roser 2015).

At the time of Independence it was clear that engineering was to play an important role in India's development, and naturally so. India had begun as a poor country with few material resources and fewer means of their production. Steel, for example, was added at roughly 4 kg per capita per year, i.e. barely enough for a *pucca* house for a miniscule fraction of the population, or an even smaller investment in infrastructure. Agricultural yields, e.g. at 1,000 kg of wheat per hectare, were already low and falling. In most of the Deccan plateau and South India, agriculture was largely rain-fed and prone to failure. Ambedkar, in his analysis of small agricultural holdings, was a strong advocate of industrialisation, which would serve two objectives: reduce the pressure on land and produce much-needed material goods.

There was already existing in India a tradition of the engineering college, albeit in the idiom of the colonial project and its instrumental needs. Historically, the earliest engineering colleges in India were the Thomason College (1847) at Rourkee, Colleges of Engineering at Pune and Shibpur, near Kolkata (both in 1856) and at Guindy (1858). All were started by the regional colonial administration, and their charter was to satisfy the demand for engineers and designers

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of public works. An eminent alumnus of Pune (in 1888) was Sir Visvesvaraya, who went on to design several important irrigation projects in the states of Hyderabad and Mysore. Many later graduates went on to lead industry houses. The next batch of colleges arose in the period 1910–47, which included the Dhanbad School of Mines, colleges at Jadhavpur, Benaras, Patna, the Indian Institute of Science at Bangalore, and others. Many of these colleges had begun as polytechnics with a shorter course, called the 'licentiate' or the 'diploma'. This course was usually for preparing manpower for operational positions and did not include design. All told, at Independence, India had about 38 engineering colleges that were graduating roughly 2,500 engineers, and about 50 polytechnics graduating about 4,000 students, every year. Two eminent private colleges were the Businayana Mukundadas Sreenivasaiah College at Bangalore and the Birla College at Pilani.

The development of science in India is more complicated, linked as it is with the colonial experience of early Indian scientists and the role of culture in the conduct of science (see, for example, Kumar 1995). But it was also more influential in the formulation of policy and institutions of engineering education. Perhaps, the country saw its first *professional* or *salaried* scientists and engineers in those who came with the colonial administration to survey, document, and exploit the resources of the colonies. These scientists and engineers were first-class scientists in the European scientific tradition and yet created extraordinary value for the colonial state. Moreover, Indian intellectuals were also familiar with the scientific methods of the West by actually having visited their universities. This led to the formation of Indian science as a conflation of big science – i.e. science as a salary-paying institution of the state – with high science – i.e. science of the well-funded laboratories – and the dream of moulding it to serve the Indian poor. This vision influenced the Indian elite in their conception of the role and methods of science and technology in India and their own agency. This vision was present in the first planning exercise of 1936 of Sir Visveswaraya, and took more concrete shape in subsequent national plans. These plans eventually led to the establishment of the National Chemical Laboratory, the National Physical Laboratory, and other centrally sponsored laboratories as the first national investment in science. Following that, they led to the formation of the centrally sponsored Indian Institutes of Technology (IITs) and then to the Regional Engineering Colleges (RECs, now called the National Institutes of Technology, or NITs) as the first investments in technology. This network of institutions now constitutes the core of the scientific bureaucracy in India.

This vision was also reflected in the holding of the portfolio of science and technology (S&T) by the highest executive office in the country, the Prime Minister, and a nominal role for provincial governments in S&T policy. This centralisation of conduct of S&T persisted till the 1970s, when the first few state commissions were formed. The centralisation of expenditure continues to this day. It is also instructive that in many speeches by Pt Jawaharlal Nehru, especially those at the launch of the various central institutions, we find both a reference to the 'autonomy' of S&T and yet an exhortation for it to work for the deliverance of the common Indian from the 'grinding poverty' that traps him. But there were very few concrete mechanisms proposed or any concrete accountability that would bring these institutions close to the day-to-day problems faced by the provincial governments in bringing development to their poor citizens. The top-down view also missed the rather important role that small inventors, artisans, and amateurs had played in the development of Western science. It also missed the historical continuity and the deep civil society processes that had supported and shaped it.

Coming back to engineering, at Independence there were three central (overlapping) expectations from engineering as an institution. These were articulated by the Sarkar Committee report[3] of 1946 as the manpower and research needs for (1) management and development of

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key resources such as water and energy; (2) development of basic infrastructure and heavy industry; and finally (3) the supply of trained engineers for industrial production of material goods in the private sector. One may add to this the constitutional vision of a modern Indian people equipped with a scientific temper, who have risen above caste and superstition. Given the enormity of the problems, it was felt that the existing institutions were not adequate and a national investment was required.

We will divide the post-Independence growth of engineering education into three broad phases marked by three key policy choices. Each is remarkable in its own way and had important consequences for the conduct of engineering in India.

Phase I: the foundations

The Sarkar Committee report led to the first visible investments by independent India in engineering education, namely the setting up of the centrally funded and autonomous IITs. Soon after this, a recommendation by the Planning Commission led to the founding of 20 RECs. The RECs were also autonomous and founded by the Centre, but the running costs were shared with the states. While the IITs were to focus on excellence in research and the 'scientific' development of engineering, the RECs were to satisfy the demand for engineers in regional development projects.

The design of the first IITs was carefully done. In the Sarkar Committee report itself was the mention that the IITs must be modelled after the Massachusetts Institute of Technology (MIT) or the Manchester Institute. Correspondingly, an abstract disciplinary scientific engineering curriculum, as opposed to the practice-based curriculum of existing colleges, was carefully drafted and generous capital as well as running expenditures were requested and approved. A faculty nurture-and-mentoring programme was set up to prepare teachers of this scarce and special knowledge. IIT Kanpur was mentored by the USA, and IIT Bombay by the then USSR. Proximity to the West, complete autonomy in academic matters, an exclusive curriculum, a large budget outlay, a monastic residential campus for each IIT, and a nationwide competitive admission exam pushed the IITs into the national imagination. They were an immediate success with the middle and upper classes. However, right from the first year, many IIT graduates chose to migrate and the phrase 'brain drain' came into the popular lexicon (Sukhatme and Mahadevan 2004).

The IIT system had several important socio-political features: (1) it was the first indigenous elitisation, i.e. a systematic construction of elite agents and a belief in their ability to transform;[4] (2) it was supported by a belief in the excellence of a text-based analytic S&T which was visibly linked to elite institutions of the West, and not to field experience of existing institutions or agencies; and finally (3) a *physical separation* of science into the elite and the common, and a physical removal of the elite from their social milieu. The elitisation was implemented by creating a national system of 'merit' to be measured through nationwide competitive exams and a cloistered system of centrally funded institutions, removed from the hurly-burly of the regional universities. *Thus an elite, scarce, and transcendental knowledge system was created.* Remarkably, all of these features – elite agency, abstraction, scarcity, selection, and separation – have spread to other disciplines and continue to be the pillars of Indian higher education. The separation of engineering students, both from society and from the social sciences and arts, in curriculum as well as in location, persists to this date.

Next, the old colleges, the IITs and RECs, were further complemented by a system of government engineering colleges (GECs) within each state. Most of the GECs were not autonomous, but affiliated to various regional universities. The IIT and REC system first sat in

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parallel to the older premier colleges of Rourkee, Pune, or Benaras, and specialised institutions such as the Department of Chemical Technology at Mumbai (UDCT) and the Dhanbad college. Eventually, however, these older institutions were eclipsed by the new institutions, largely because of greater financial outlays, administrative autonomy, a more competitive student body and better outcomes for its graduates *outside* Indian engineering. Ironically, the possibility of exactly this outcome was pointed out by two dissenting notes in the Sarkar Committee report. Surprisingly, the RECs were not modelled after the land-grant universities of the USA, with their strong regional connection. In fact, most of the RECs have no academic programmes of regional relevance. This was further cemented in 2007 by the Centre renaming the RECs as NITs and taking over full control. Thus, an important bridge for the states to connect with the Centre and to organise their engineering system was lost to the Centre.

Phase II: growth and decoupling

The number of engineers graduating every year grew steadily so that in 1987 there were about 30,000 graduates from about 300 institutions, most of which were state-funded. The output of the IITs were about 1,500, i.e. about 5 per cent of the total. However, in the late 1980s, the IT boom began and this led to a proliferation of the private engineering college. The All India Council for Technical Education (AICTE), though formed as an advisory body in 1945, was empowered in 1987 to regulate the entry of new colleges and to ensure that student interests were protected. These colleges were required to demonstrate adequate finances, equipment, space, and qualified faculty members, for example, to meet AICTE requirements,[5] and site visits by AICTE inspectors were dreaded events. Most private colleges would still affiliate themselves to state universities for their curricula and examinations, and that was generally found acceptable by the AICTE.

The numbers of graduates and institutions rose rapidly to 120,000 and 400 institutions in 1997, 187,000 in 2000, and 550,000 and 1,600 institutions in 2006. By 2014 there were over 1,000,000 students graduating from about 3,000 institutions.[6]

The sheer enormity of these numbers is without parallel around the world. For example, about 110,000 engineers every year from about 400 engineering colleges suffice for the USA. What these numbers do not show is a severe loss of quality and distortion of engineering education in India. This increase was largely because of the boom in the IT sector, which grew from 240,000 employees in 1999 to 690,000 employees in 2005, to about 13,000,000 employees in 2009, and used engineering colleges as recruiting grounds. While the colleges responded by expanding their seats in the IT-related streams such as IT and CS/CSE, IT firms would gladly poach from other streams of engineering as well. This practice continues today. For example, in 2012, the IT sector hired 65 per cent of the graduating batch of 440 at GEC Thrissur, most of whom were not from the CS/IT branch. At IIT Bombay, too, in 2013 the IT sector hired about 24 per cent of the graduating enrolment, of which only about half came from the CSE stream.

Thus, the IT boom effectively converted the engineering college into an *aspirational* marketplace for English-speaking and well-paying, intermediate economy service sector jobs. This caused many distortions within and without college. Core engineering companies found it difficult to find fresh engineers at reasonable salaries. IT and CS departments faced a faculty shortage, while core engineering departments faced a lack of student interest. This was visible in macroeconomic indicators as well: it was service sector employment, especially in IT and communication services, that grew the most and best rewarded tertiary education. This decoupling of engineering jobs from engineering education was one important outcome of this phase. Ironically, an important impetus to this 'de-industrialisation' was provided by the World Bank

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project IMPACT (1989–1993), which trained faculty members of engineering colleges to teach an IT/CS/EE curriculum.

The IT boom was a precursor to the overall service sector boom for fresh engineers and was again led by the IITs. By this time, given the number of engineering graduates, the IITs were graduating about 1 per cent of the total number of graduates. These elite found jobs in the financial and consulting companies, and global IT majors, as more rewarding and better paying, than engineering companies catering to domestic needs such as cement or construction companies.[7] The high salaries of a few IIT graduates fed into a thriving coaching class industry of several hundred billion.[8] This led to the second decoupling of the actual aspirations and trajectories of IIT students from the stated charter of the IITs as an institution. All the same, its reputation as a global merit-based technological institute was crucial for the branding of the IIT graduate.

It also marked the emergence of 'brand IIT', of the smart and well-marketed institute, a national example of global values of knowledge and merit, iconic jobs for a few graduates, and yet an underbelly of a huge coaching industry and inordinate media attention. This emergence was driven by several factors. First, the IITs had long ago exempted themselves from the AICTE and its bureaucracy. Second, they are far less accountable to regional demands and budgets, and their students better connected and more adept at industry relations and brand-building. As compared to state colleges, they also receive far more funds from the MHRD directly, and from S&T funding agencies that are typically situated at the centre. Third, and most importantly, the IITs are the high-priests of engineering education since they administer both the iconic JEE (Advanced), which defines 'scientific' prowess at the high-school level, and the GATE exam, an entrance examination for engineering graduates for postgraduate study within the IITs, which has now become the de facto standard for engineering education.

Thus, the end of this phase was marked by decoupling of engineering institutions from engineering jobs, a consolidation of the definition of engineering, and, paradoxically, elite branding and deployment of the elite engineer into global service.

Phase III: the global alignment

In 2003, the MHRD and the World Bank launched the 'Technical Education Quality Improvement Programme' (TEQIP), a Centre-sponsored scheme of Rs. 13 billion that sought to improve the overall quality of select engineering colleges across the country. Not surprisingly and without offering any analysis, the project documentation began by installing the IITs as role models and offered a roadmap for the selected 127 colleges (henceforth, TEQIP colleges) to become like the IITs. These colleges were largely government colleges, i.e. the NITs, the GECs, and a few well-performing private ones. The programme was rolled out in two phases. In phase I, participating colleges were to '(i) develop academic excellence, (ii) network with selected institutions for the benefit of faculty and students, (iii) provide service to community and economy, (iv) develop management capacity'.[9] The words 'excellence' and 'global quality' appear about 100 times in the project documentation. The roll-out of TEQIP was accompanied by (1) the formation of the National Board of Accreditation (NBA), under the AICTE, and (2) movement towards signing the Washington Protocol (which was accomplished in 2014), which committed India to a global definition and certification of engineering education.

The objectives of TEQIP translated into requiring TEQIP colleges to (1) improve academic and management processes (but not to review the curricula) leading to academic autonomy; (2) improve infrastructure; (3) accredit their programmes to the NBA; and (4) incentivise faculty members to do research and report it in national and international journals. Though provision

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of service to the community was an objective, there was very little design in the programme to actually effect it or to measure outcomes, and it largely did not happen. Shockingly, the NBA points to the American accreditation agency, ABET, as one of the references, thus in effect pushing the TEQIP colleges to accredit to ABET – i.e. to a curriculum that does not have 'sewage' as an area of study.

Phase II selected 160 colleges, largely covered by phase I, and cemented these 'global' outcomes in existing TEQIP colleges by sponsoring 'Centres of Excellence' and by initiating graduate programmes.

The outcomes of TEQIP were as designed. The number of research publications shot up and new and mysterious fields of research were discovered.[10] Actual student outcomes and their participation in the Indian engineering industry were not measured. Most TEQIP colleges adopted accreditation, which further consolidated the power of the NBA. Accreditation is now mandatory for new programmes or increasing the strength of old programmes in all colleges, new or old, public or private, *except for the IITs and the NITs*.

Requiring accreditation severely limits the space for new initiatives in engineering education, for either these must find a place within ABET or must be led by the IITs and NITs. More importantly, the TEQIP reform missed an important opportunity to respond to the inherent needs of the state agencies for new knowledge and new partnerships. It also failed to acknowledge small and medium enterprises as legitimate partners in engineering. These small producers have little access to quality control, standardisation and certification, packaging, and branding – i.e. areas where regional institutions would have helped. Thus, TEQIP failed to step outside the corporatised straitjacket of the disciplinary curriculum. Even today, most engineering graduates, including those from the IITs, have not seen any of the following as a part of the curriculum: a factory, small or medium enterprise, a public system (such as a railway station or an urban water supply system), an ordinary drinking water well, or a *chulha*. Thus, the final phase established an alignment of the top tier of engineering colleges with the global definition of engineering and also put in place a global research metric for faculty performance.

On the vocational side, the polytechnics of the early years bifurcated into the Diploma-granting polytechnics governed by the state ministries of education and the Industrial Training Institutes (ITIs), which offered training in 'trades'. The Diploma has been slowly decaying until recently. The ITIs were roughly 11,000 in number in 2014, of which about 2,500 are state-funded and the remaining are private institutions. These train roughly 1.2–1.6 million students each year. Besides this, there are the fewer Industrial Training Centres, which are integrated within large companies. Typically there is at least one state-funded ITI in a block, and perhaps several in industrial towns and cities. These are governed by the Directorate of Vocational Education, an agency of each state's ministry of industry, and receive funding and attention based on its priorities. The objectives, curricula, and pedagogy are, of course, quite different from a typical institute under the state's higher education department. Each ITI teaches several 'trades' in variable-duration programmes, but the typical course is between one and two years long. However, most courses prepare students for trades in the formal sector, which has traditionally employed a small fraction of all workers. It was only recently that several new trades – e.g. food processing – have been added which actually cater to the self-employed or the informal worker.

The input to the ITI is usually secondary or pre-secondary, and instruction is in an informal mixture of vernacular and English. A work-week is typically of 40 hours, of which more than 20 will be spent in the workshop where students work on standard machines and are trained to measure, quantify, draw, and manufacture standard jobs. Lectures supplement this material and cover aspects such as costing and safety. The ITI training is capped by an apprenticeship under

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the Apprentice Act (and its amendment) and aims to place these graduates within a suitable company for another year. The ITI has been an important avenue for rural youth to find industrial employment, but performance has differed greatly across states. While in Maharashtra the ITI graduate commands a substantial premium, it is only moderate in Tamil Nadu and even less in some other states. As mentioned earlier, it is only recently that small and medium enterprises composed of rural and cottage industries and informal enterprises have been able to articulate their training needs and also their technical and research needs – e.g. in standards, pollution control, and process modernisation – and bring these to the attention of the ITIs and broader engineering education and research.

One must mention the professional bodies in India. The Institute of Engineers (IEI) was founded in 1920 and has about 0.3–0.4 million members. It has administered a certification exam (AMIE) for the past several decades and many government bodies recognise the AMIE as being equivalent to a BE/BTech. Its recognition by private companies or other universities is doubtful. The IEI also publishes a journal that is popular with regional colleges. The Institute of Electronics and Telecommunications Engineers (IETE) is a sister body of the IEI. The 'official' Indian National Academy of Engineers, a government-supported body, started only in 1987, and does not publish a journal.

The outcomes

The most alarming outcome is the hollowing out of the engineering academia. Elite institutions have chosen to preserve their 'autonomy' and remain subservient to the global research culture. And they have arranged their incentive structures accordingly (Sohoni 2012). Barely one-third of their graduates work in Indian engineering, and barely one-fifth of their research funding comes from the industry. As a result, they have very little practical knowledge to offer to its graduates, the industry, or the state. Research on real-world problems, i.e. on 'provincial' issues remains largely non-existent. There are barely a handful of Indian journals of any repute. For institutions lower down, the projection of the IITs and their curricula as role models, the forces of 'global knowledge', and the bureaucracy of TEQIP and the AICTE have made them feeble players.

The obvious corollary of this is a uniformly poor quality of education and a job market which is completely driven by brands and perception. For example, in the JEE (Advanced), the entrance exam for the IITs, close to 90(!) of the top 100 students choose to study either at IIT Bombay or IIT Delhi. This is hardly indicative of the quality of education that these provide or other IITs fail to provide. It has more to do with a vicious cycle of multinational service sector companies offering multi-million 'packages' to graduates from these institutions, which acts as the magnet for 'the best'. This sets up the *aspirational dysfunction* in the engineering profession: a few globalised jobs of high wages, a redefinition of the practice of engineering, and a well-marketed system of merit, i.e. the JEE. The JEE is based, presumably, on the autonomy and excellence of science, but whose principal function is to offer a 'fair' argument to reject the 98 per cent, perpetuate elite agency and its global linkages, and bolster the legitimacy of the Indian elite knowledge bureaucracy. As before, provincial governments and their colleges are unable to play this aspirational game or to contest this notion of science. Nor can they fight this usurpation of a regional curricula which, if designed well and without this severe distraction, may offer local relevance, and a system of smaller rewards, but for a large number of graduates, at lower costs and substantially better odds.

So is this competitive science and engineering competent enough, i.e. does it have a body of knowledge and is it effective? These two questions strike at the essence of engineering as a

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profession, namely expertise and agency. The instinctive answer is of course, a guarded YES. Are we not building tunnels and bridges? Do we not have mobile coverage over most of India? Are we not one of the biggest manufacturers of steel? However, it is instructive to look deeper into each of these engineering activities. Consider, for example, the standard workhorse of Indian Railways, the diesel locomotive engine WDM2 of 1962 to the current WDP4 introduced in 2001. Both are imported designs which were re-engineered here in India. The plan for the new 6,000 hp engine is also to import the technology and re-engineer and not to develop it in-house.

If we look at the wellbeing of our people, our life expectancy at 65 is the lowest among all our neighbours, and lower by a full ten years than those of China and South Korea, which had comparable numbers in 1947. Next, in the basic engineering services of drinking water and cooking energy, about 70 per cent of our rural households still use biomass in *chulhas* as an energy source. Year-round access to drinking water has actually fallen.[11] This is largely a result of the failure of the state in managing knowledge and practice. For example, do we know how much water flows in our rivers to implement a reservoir control regime? Why do water supply schemes fail? Or how does sugarcane in Pune district affect drinking water availability in Marathwada? More generally, what is the traffic on Indian railways and optimal schedules for them? Or how to build network routers and manage watersheds? Unfortunately, the answer to all of these questions is 'No'. There is no systematic knowledge *and* agency in any of these areas. The Indian state remains woefully short on scientific processes, analysis, and training, and must work without any support from its research institutions. And this is aggravating core development outcomes such as drinking water, cooking energy, and public transport.

Looking at the private sector, consumption of engineering goods has increased, but so have imports and charges for intellectual property. Multinational companies have ramped up their royalty payments while spending large amounts on marketing and brand-creation (Varman 2014). They are spending less than 1 per cent of their revenues on R&D. Investments in research by domestic companies remains tepid and their linkages with research institutions remain weak. The import bill on electronic equipment is now close to what is spent on importing hydrocarbons. The fraction of India's GDP contributed by the engineering industry has steadily decreased. Salaried jobs in manufacturing have decreased and casualisation has increased. Agriculture remains the largest employer by far. Small enterprises with low productivity, poor quality, and absent branding remain the backbone of employment in manufacturing. And these have been unable to penetrate the more profitable urban middle-class markets, thereby allowing rent extraction by large branded companies.

India remains a poorly engineered society. Many state agencies are in a downward spiral so that we now hear of 'minimum government, maximum governance'. The development agenda, i.e. reduction in poverty through better knowledge in the core sectors, resource management, and industry, the very basis of our investments in engineering education, remains well outside the training and research of the engineering system.

Finally, has the culture of science or the access to it changed? Has science and engineering helped the common man understand and manipulate his material world, or comprehend the activities of the state or the market? Do we have a collective understanding of how to face repeated droughts? Is there a civil society to apprehend or comprehend on his or her behalf? Unfortunately, again, the answer is a resounding 'NO'. The public imagination of science remains in elite capture as it has been for the last 50 years. It is now managed by the IITs, IISc, IISERs, and their funding agencies, as the singular pursuit of a high science for an eventual greater common good, and of a global race which we will, *nay must*, win. For students, it is thus limited to the 'fair' *merit* to locate the top 2 per cent in national exams. Repeatedly, through

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various programmes (such as the Kishore Vaigyanik Protsahan Yojana), national agencies identify the same set of 'gifted' students and reward them and reaffirm their faith in elite agency. Excluded from it (statistically) are the poor, the rural and the vernacular, girls, and students from State Boards.[12]

Curiously, this competitive 'science' of the 2 per cent may have the vocabulary of refractive indices, aldehydes, and ketones, or the *latus rectum*, but there are no people in it and no events. It has no biographies and no role models, e.g. of the illustrious chief engineer, the neighbourhood factory or rice-mill owner, the local blacksmith, or the girls on their machines in the village handloom. It has no measurements, no theorising, and no comprehension. Nor does it have the design of experiments or of arguments. It does not measure, e.g. the efficiency of *chulhas* in a village, or argue for better bus routes. It has no case studies, no piecemeal social engineering, no memory of repeated droughts, and no accounting of the long trips to fetch firewood. It has no agency, nor a theory of causation and no outcomes for the bottom 98 per cent. *In fact, it is a bureaucracy which will never have the idioms and dialects necessary for a true science to emerge.* No, Indian science and engineering does not answer 'Why am I poor?' or 'Why did my child die?'

Where do we go from here?

This is a difficult question but let us begin with some observations.

Four observations

One, much of science and engineering for a society are closely aligned and operate on a common mechanism. This cyclic mechanism is of a paired system of vocabularies, one which is external, e.g. natural or social, and the other which is internal or conceptual and a feedback loop. The loop is composed of cultural skills of (1) translation, i.e. of theorising and validation, or in engineering, of design and implementation; (2) a theory of outcomes and of soundness; and (3) a rigour, i.e. a process of accumulation of knowledge. A system of rigour may well be empirical, i.e. borne out of experience, or may seek tight mathematical relations between the two vocabularies or a combination of the two. Each of these is a social and cultural choice, and also depends on prevalent ideologies or *schools of thought* for repairing faulty theories. Thus, a science for a society is determined by various material as well as cultural realities. A potter, a theoretical physicist, an urban planner, and a professional violinist from within a society will each have a different science, and the tapestry of such sciences is the *scientific culture* of that society.

Two, what is claimed as global science and technology is actually such a tapestry of cultural outcomes of the pursuit of the West for its own material and cultural wellbeing. This science has been developed by both amateur and professional scientists, by political agents, and shaped and chiselled by the many scholarly and popular critiques of *cultural* and *philosophical* agents. Its libraries and journals, the Ivy League, Fermat's Theorem, the Bunsen burners, and round-bottom flasks are artefacts of this pursuit. None of these are predestined to be on the trajectory of every culture in its hunt for its science and engineering. Many of the West's programmes, such as anthropometry in the past, or neoclassical economics and genetic biotechnology of the present, are fraught with danger. Moreover, the West itself is going through a crisis of elite capture, but more on that later.

Three, there is a great reliance of elite Indian institutions on the borrowed rigour of Western science and engineering and its artefacts such as journals, universities, and institutions, and therefore on its external and internal vocabulary of describing society. Much of this reliance is

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hard-wired into professional curricula and career advancement within academia and also within large national and multinational corporations. This is accompanied by an insistence on the apparent 'autonomy' of this borrowed science as being its true nature. There is also a great confusion regarding the very nature of rigour and whether Indian problems are actually amenable to rigorous articulation and solution in the chosen vocabularies. The answer to this last question is, of course, 'No'. The claim of universality of Western science by a few agents of the West or our elite must be viewed as arising from this confusion, or as the purely strategic objective of rent-seeking, or finally as the intellectual laziness in constructing the required vocabularies and systems of rigour and soundness. The water sector, or for that matter computer science and engineering, in India presents us with examples of all of the above.

Finally, Western science has now been superseded by a modern *global science*, an agency of the global economy. This is a coalition of iconic researchers spanning all disciplines of knowledge, multilateral agencies, and elite institutions which seeks to propagate and consolidate elite agency. It does this by insisting on (1) an idea of a 'rational' behaviour which is natural, i.e. without culture or politics; (2) an idea of a scarce and rarified science of breathtaking power and global reach, i.e. an overarching explanation for all phenomena, regional or global; (3) an insistence on 'gold standards' for evidence, thereby controlling the legitimacy of regional studies by regional agents and restricting its impact on the conduct of science; and finally (4) appropriation of words such as Development Economics or Development Engineering[13] to deal with the 'irrational' world, and to put their usage under expert supervision. It obviously sees a useful client in Indian elite science.

The way ahead

The way ahead is to set aside the hegemony of a scarce and transcendental science and build the empirical foundations for a broader and more democratic knowledge formation. This new science should move away from the purely disciplinary and industrial employee-engineer to a model of the engineer-scientist as a social agent. It should prepare our youth for a more direct role in probing their material reality and to try to change it. The exact design of such a science and engineering must be done carefully for it must slowly disentangle itself from the 2 per cent outcome game of elite science and its aspirational ladder. On the other hand, it must engage with the small and medium enterprises, the core sectors of agriculture, water, energy, and environment, and local agencies and state departments. The state should, in turn, see these social agents as essential collaborators if it must ride over the severe environmental stresses which lie ahead.

This must begin with hundreds of rigorous case studies that students can execute and which formalise the problems in their vicinity and thus set them up for discussion and eventual solution. These may be, e.g. templates for government programmes such as the watershed programme, or energy and technology audits of neighbourhood enterprises, or computer models of urban water supply systems. Over the years, these case studies will develop into a body of knowledge and of practitioners who will deliver engineering value to the community. It will define a new and innovative profession – the *vernacular engineer* – as one who is well-versed with the interdisciplinarity of everyday life, the normative concerns of community development, and who can access various disciplinary skills to deliver solutions. It will define a rigour of its own, which is sound, which has agency, and yet which is accessible to the community to contest and refine. The faculty member is then a community consultant as well as a role model, and the institution the regional knowledge resource. Such an approach will restore science and engineering as the cultural pursuits they really should be.[14]

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Broadly speaking, a cultural and convivial society and a matching science and engineering is the only path that will avoid the ‘rational’ traps of modern *global science*. Perhaps, more importantly, it will empower us as a society to understand that the contours of the state and the market, and even of science, depend on the *consumption* choices that we make. Ultimately our consumption, and what attributes we choose to discern in it, will decide the modes of production and the knowledge of that society to produce it. If we must have branded and world-class (but mass-produced) goods offered by a few iconic companies, then science must locate the ‘top’ 2 per cent to manage such companies, and shove a lot of wealth and power into their hands. If we must live longer at any cost, and track every courier package online, then our science will create cocoons of managed environments for a few of us, while the rest of us, and our co-habitants on this planet, must stay in a largely degraded and unstable biosphere. It is this *cultural* choice of consumption that will underpin the viability of the vernacular engineer and the sustainability of our diverse society and its environs. Perhaps it is the only path to ensure that the beauty and bounty of the seasons and a teeming multitude of cultures and organisms remain on this earth.

Conclusions

How does all this connect with the broader contours of higher education in India? First, the focus on numeric and universal targets of access, equity, and quality hides an essential confusion about the destination society for which the design of higher education is needed. Only after this confusion is resolved can the objectives of higher education be stated and the choice of a curriculum and pedagogy, of rewards and recognitions, be made.

The heart of this confusion actually lies in the theory and practice of Indian social science. It comes from the inability of elite Indian social science to see vernacular life and the vicinity as subjects of common study and vernacular practices as possible instruments of change. Or perhaps from its fear of an unreconciled past placing unforeseen obstacles in forging a culture for the future. In engineering, it appears simply as an unsaid commitment to a corporatist society as a matrix in which culture may be expressed, and a devotion of the state’s energy and treasure to train employees for this future society. It ignores, as we have argued, the agency of cultural agents and the historical antecedents of Western corporate societies, our role models, and their

Table 10.1 Starting jobs by sectors for IIT Bombay graduates in 2013

Placements IIT Bombay 2013				
Sector	*Engineering*	*Finance*	*Consulting*	*IT*
Super-GG	25 (2.77)	10 (3.5)	7 (5.4)	42 (5.13)
GG	116 (0.79)	82 (1.17)	110 (0.96)	102 (1)
IG	54 (0.65)	19 (0.72)	11 (0.58)	28 (0.72)
GI	24 (0.93)	10 (1.42)	10 (0.52)	5 (0.93)
II	64 (0.65)	13 (0.95)	8 (0.58)	22 (0.79)

Source: All tables in the chapter are compiled by the author; prepared by the author from data provided by the Placement Office, IIT Bombay.

GG refers to a global company serving a global market (e.g. Bank America or General Electric), while II refers to an Indian company serving the Indian market (e.g. Ambuja Cement or Tata Motors). IG and GI are similarly explained (e.g. Infosys and Hindustan Unilever respectively). Super-GG are placements abroad. The number, e.g. 116 (0.79) indicates the number placed and the average annual salary in rupees (million).

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Table 10.2 Average household spending on education by families having one studying member

		Andhra Pradesh Urban	*Andhra Pradesh Rural*	*Rajasthan Urban*	*Rajasthan Rural*	*Odisha Urban*	*Odisha Rural*	*Tamil Nadu Urban*	*Tamil Nadu Rural*
Households with one studying male	Mean (Rs.)	9,919	5,706	19,096	4,362	5,765	1,787	11,046	8,493
	Number of samples	365	373	235	263	143	291	373	293
	Gini	0.61	0.58	0.56	0.64	0.65	0.70	0.64	0.67
Households with one studying female	Mean (Rs.)	9,233	3,752	9,369	3,431	4,278	2,292	12,653	6,949
	Number of samples	281	245	98	126	94	191	321	259
	Gini	0.61	0.55	0.60	0.56	0.82	0.76	0.65	0.69

Source: the author's analysis of 68th round data, NSSO, 2012.

Table 10.3 Number of papers published with at least one Indian author, by word appearing in title of the paper: novel areas of research

Topic (Phrase)	*All years preceding 2003*	*2003–09 (TEQIP I)*	*2010 onwards (TEQIP II)*
Neural network	692	1,818	2,467
Fuzzy logic	110	327	759
Wavelets	96	905	1,846
Genetic algorithms	262	989	1,373

Source: prepared by the author from data obtained from Scopus, an online catalogue of scientific publications.

Table 10.4 Number of papers published with at least one Indian author, by word appearing in title of the paper: research in engineering services

Topic (phrase)	*All years preceding 2003*	*2003–09 (TEQIP I)*	*2010 onwards (TEQIP II)*
Water supply	84	74	87
Sanitation	30	51	63
Groundwater models	11	29	70
Public transport	5	15	25
Power grid	12	56	288

Source: prepared by the author from data obtained from Scopus, an online catalogue of scientific publications.

Table 10.5 Statistics of students appearing for and qualifying for entrance to the IITs by gender

	JEE 2012			*JEE (Advanced) 2013*		
	Appeared	*Qualified*	*Pass (%)*	*Appeared*	*Qualified*	*Pass (%)*
Boys	337,916	21,226	6.28	103,660	18,468	17.8
Girls	168,568	2,886	1.71	23,089	2,366	10.2
Percentage girls	33.2	11.9	–	18.2	11.4	–

Source: prepared by the author from various publicly available sources.

Table 10.6 Statistics of students appearing for and qualifying for entrance to the IITs by place of passing the XII standard (%)

	JEE 2011		*JEE 2012*		*JEE (Advanced) 2014*	
Cohort	*Registered*	*Qualified*	*Regsitered*	*Qualified*	*Registered*	*Qualified*
Village	19	10	19	11	13	10
Town	29	25	29	26	19	14
City	52	65	52	63	68	76

Source: prepared by the author from various publicly available sources.

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science and engineering. As a corollary, it pays scant attention to the knowledge needs of the vast number of non-corporate entities – the small enterprises, the district administrations, the elected representatives – who serve an increasing fraction of our population. It also ignores the incomprehension of the vernacular student who must look at her own immediate material environment with great detachment, become 'globally competitive' and yet not be assured of such a job. It ignores that the skills of *manipulation, articulation, description and argumentation* are essential to any science and that the vicinity is the real laboratory.

How will this change? Indian science lacks both an *external* as well as an internal critique. The internal non-elite critic has been delegitimised by elite capture. The absence of a systematic external critique is more remarkable, for it is the dog that did not bark. It perhaps hides vested interests within other areas of our academe or a true confusion about where our society is headed. For the social sciences, elite or vernacular, this constitutes an important responsibility which they must squarely face. They must design alternative worlds for a diverse society such as ours and inform us on our choices. They must tell us what is amenable to science and engineering and what is not. They must tell our vernacular youth *what is worth learning and who are their role models*. Must we chase mirages of global jobs or resign ourselves to 'skilling' for mundane temporary jobs? Is there anything in my decrepit world which is beautiful which I must learn to describe? Is culture malleable? How do I articulate and argue for a different social reality and bring it into existence? Can both knowledge and agency exist within me? Can I and my community forge a common future? *Or is escape for the few the only solution?*

Notes

1 A broader discussion by this author, of engineering and society and the creation of value, is available as *Knowledge and Practice for India as a Developing Country*, at www.cse.iitb.ac.in/~sohoni/kpidc.pdf (accessed on 12 October 2015). A shorter version was published in *Seminar* in February 2014.

2 See, for example, the agenda of the Institute for Complex Engineered Systems at the Carnegie Mellon University.

3 The Viceroy's office set up the Sarkar Committee in 1946 to consider the setting up of new institutions for the industrial development of India. An online version is available at: www.iitsystem.ac.in/admin/SarkarCommitteeReport.pdf (accessed on 12 October 2015).

4 By an elite class, we mean (1) a class which has inordinate influence as compared to its size, and (2) an acceptance of this influence as being reasonable. See, e.g. Gramsci's writings on cultural hegemony.

5 *AICTE Approval Process Handbook*, published every year by the AICTE, India.

6 See statistics available at AICTE website. Also see Banerjee and Muley (2007).

7 See Table 10.1, taken from author's submission to the AICTE, available at www.cse.iitb.ac.in/~sohoni/commentsAICTE.pdf, and which is to appear in the *Current Science* journal. It illustrates that much of the IIT Bombay goes into the global services sector, that which is left is pressed into engineering services for a global society.

8 The NSSO data also reveal that households are spending huge amounts on education and that there is great inequality in this spending across states, across genders, and across rural and urban households. See, for example, Table 10.2.

9 TEQIP phase I and II documents are available with the National Project Implementation Unit of MHRD. They are also available online at: www.npiu.nic.in/archives.htm (Phase I) and www.npiu.nic.in/ongngprj.htm (Phase II) (accessed on 12 October 2015).

10 Research areas such as 'Wavelets, Simulated Annealing' and 'Genetic Algorithms' have thousands of papers published by Indian researchers (see Tables 10.3 and 10.4). Thus, we see a proliferation of areas of research with little practical relevance, and very little research on our basic engineering systems such as groundwater or electricity.

11 This is seen from various rounds of the NSSO survey on basic amenities or by the census data of 2001 and 2011.

12 See Tables 10.5 and 10.6. Girls constitute only about 11 per cent of the total student strength in the IITs. This is in stark contrast to the fact that about 30 per cent of engineering students are now girls.

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Moreover, in the less competitive CBSE XII exam, girls excel at all levels. Similarly, about 11 per cent of IIT students come from rural backgrounds. More than 70 per cent come from cities (as opposed to towns). More than 50 per cent of students who succeeded in the JEE (Advanced) 2014 were from the CBSE.

13 See, for example, the composition of the editorial board of the highly regarded journal *Development Economics*, or the new journal *Development Engineering*. Also see the scope of these journals and their notion of rigour.

14 One step in this direction was taken in October 2014 by the launch of the *Unnat Bharat Abhiyan* (http://unnat.iitd.ac.in) by MHRD, which mandates the IITs to (1) build an understanding of the development agenda as an academic pursuit; (2) to bring interdisciplinarity, stakeholders, outcomes, and fieldwork into the curricula; (3) to work as a regional knowledge resource by consulting with local bodies; (4) to improve development outcomes by collaborating with state agencies; and finally (5) to foster a broader dialogue on science, society, and environment. It also requires each institution to form an *empowered* cell to execute the programme. The mandate thus requires the IITs to recast their incentive structures. Moreover, the *abhiyan* offers a unique window of opportunity for state governments to reclaim the science and engineering agenda and use elite institutions as a part of their regional knowledge infrastructure. Most importantly, through provision (3) it makes the elite institutions accountable to the common person for his or her knowledge needs. In principle, by citing the *abhiyan*, a *gram panchayat* may approach an IIT to analyse their water supply problems. The programme does not come with attached funding; this must be found within each state's governance processes. Locating such processes (which are ample) and aligning them with the *abhiyan* should be an agenda for civil society organisations to pursue with their state governments. In January 2015, the state of Maharashtra launched the Unnat Maharashtra Abhiyan (see www.dtemaharashtra.gov.in/teqip/CMS/Content_Static.aspx?did=325 or www.ctara.iitb.ac.in/tdsc/uma, the mirror site hosted by CTARA).

References

ACSE. 2008. *Civil Engineering Body of Knowledge for the 21st Century*, 2nd, edn. American Society of Civil Engineers.

Banerjee, R., and Muley, V.P. 2007. *Engineering Education in India*. Observer Research Foundation.

Kumar, Deepak. 1995. *Science and the Raj:1857–1904*. Oxford University Press.

Nowotny, Helga, Scott, Peter, and Gibbons, Michael. 2001. *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Polity Press.

Polanyi, Karl. 1944. *The Great Transformation: The Political and Economic Origins of our Time*. Beacon Press.

Roser, Max. 2015. 'Our World in Data'. http://ourworldindata.org (accessed on 12 October 2015).

Scharf, Robert and Dusek, Val (eds). 2014. *Philosophy of Technology: An Anthology*, 2nd edn. Wiley Blackwell.

Sohoni, M. 2012. 'Engineering Teaching and Research at the IITs and its Impact on India', *Current Science*, 102(11): 1502.

Sukhatme, S.P. and Mahadevan, I. 2004. 'Brain Drain and the IIT Graduate'. *The Economic and Political Weekly*, 39(2): 285–293.

Varman, R. 2014. 'Royal Treatment of Foreign Investors'. *Aspects of Indian Economy*, 56. http://rupe-india.org/56/royalties.html (accessed on 12 October 2015).