COMMENTARY

Engineering teaching and research in IITs and its impact on India*

Milind Sohoni

This note analyses the nature of research and development (R&D) as it is practised in our premier engineering institutes and its effect on India's development. I argue that the dominant paradigm of R&D is too abstract for it to be accessible to a wider set of students and teachers, and for it to yield developmental dividends. Furthermore, our metrics for R&D are too 'international' to incentivize work on our own development problems. I contend that good engineering must train students to model societal problems and solve them, and that problems coming from our development needs are good vehicles to promote it. Finally, I make some recommendations to make engineering more inclusive and outline the role of the engineering college as a regional solution provider.

This note is an analysis of the structure and nature of research and development (R&D) in engineering, as I see it. Much of my professional life has been at the Indian Institute of Technology (IIT) Bombay and that will serve as a running example for this analysis. I must add that in the case of IIT Bombay, its best years are still to come.

I report here about R&D in engineering, as opposed to 'pure' or 'blue-sky' research. In what follows, I argue for four basic contentions: (i) there is a lack of diversity in the prevalent engineering education paradigms in the country; (ii) the dominant paradigm is too abstract to inculcate a suitable and broad-based R&D ethos; (iii) this paradigm is perpetuated by the Joint Entrance Examination (JEE) and Graduate Aptitude Test in Engineering (GATE), and these adversely impact our R&D efforts and finally (iv) our pursuit of international research is misplaced.

At the end, I suggest a possible change of course, based on notions of engagement, delivery and accountability in engineering.

Nature of R&D

While reporting about R&D in engineering, I will develop it along two lines, viz. (i) the subject matter and motivation of our current R&D, which will occupy much of this note, and (ii) a new methodology of R&D, which I will outline towards the end. Another observation: for a good education/research institute, one cannot really separate R&D and its practice from curricular teaching. This is because good R&D practice demands domain knowledge and skills which will form the basis for curricular training, and curricula define the first perspective by which students will approach new problems. Besides this, specific research examples serve as important case studies whose relevance in the classroom is well-documented. In this sense, the selection and development of curricular material should go hand-in-hand with the agenda for research.

One piece of notation: there are two types of outcomes of a good education, viz. 'conveyance', which enables one to migrate from one society to a better or more attractive one, and 'elevation', which leads to a betterment *in situ*. We may extend this to educational institutes, and call them as 'conveyor belts' (e.g. coaching classes, English-speaking lessons) or 'elevators' (e.g. electrician course, engineering at the Massachusetts Institute of Technology (MIT)). It is clear that 'conveyor-belt' education will be more about the target society, whereas 'elevator' education will be more about the current one.

My next observation is that the engineering profession is actually fairly social. It began, as with potters or carpenters, by interpreting societal needs in the application domain and its translation into the solution domain. For engineers, this solution domain is the applied physical sciences, i.e. the world of gadgets, computer programs, pipelines, reactors and such. Of course, there are many other such social professions, e.g. the doctor, the architect, and so on, while many are much less so, e.g. the astronomer, the mathematician and the botanist. Clearly, if you were an engineer, your research would be more solution-driven, and if you were an astronomer, you would enjoy more of 'blue-sky' research. Thus, just as for the fields of medicine or architecture, good engineering is about societal problem solving and is best taught in the elevator-mode, as a partnership between ambient society and the budding professional. The bottom line of good engineering is the solution of the problem posed by the end-user in society.

Coming back, important components in the practice of good engineering are: (i) good modelling skills – that of observing societal problems and their translation to the solution domain and (ii) good domain skills from where solutions will arise.

However, if we look at our engineering curricula, we will see a great deficit in courses on societal modelling and a great surfeit in the technical and scientific domain. Of course, there are some avenues for 'design', such as the B Tech or M Tech project, but here too, largely, the problems are from the discipline itself, as opposed to from society. There is one good reason for such a one-sided training and several bad ones. The good reason is that in a developed society, there is an important third player besides the society and the institute, and that is the company. A developed society has complicated needs, such as national defence or multi-continental cuisine and it is the job of the company to interpret societal needs and devise solutions. These solutions are also complicated and require many disciplinary professionals to work together. Moreover, the disciplinary skills required may also be complicated, needing many years of training in a single aspect of one particular phenomenon, e.g. microwaves or turbulence.

*A version appeared in *Raintree* (Issue 12–13, August 2011), the campus magazine of IIT-Bombay, Mumbai.

The opinions expressed here are purely personal.

This complicated training must then be imparted by the institute. Thus the developed society cycle separates the process of engineering: (i) problem modelling, specification and delivery which is done by the company, and (ii) solution, which is devised by the employee engineer. The role of the institute is to train the employee engineer.

The abstract-scientific paradigm

A large part of our engineering curricula is dominated by that of the IITs. In the late 1950s, when the IITs started, their curriculum (in turn) was influenced by that of MIT and other elite universities of the West. The West consisted, of course, of developed societies which were (and are) deeply multi-party, i.e. society–institute–company. In fact, these societies have an additional important and big player called the government. The government formulates laws, enables and enforces contracts, regulates companies, invests in institutes and so on. Further, these societies were (and are) generally well served by their companies and their governments, while we were (and are) not.

It is instructive that around the 1950s, MIT itself was migrating in its paradigm for doing engineering. Its earlier model relied heavily on neighbourhood industries such as Westinghouse, to decide curricula and to absorb its output. In fact, in 1925, the electrical engineering faculty had just 1 Ph D and was dominated by a practioner faculty with a fair amount of industrial experience. However, with the World War II and later, in the Sputnik era, a new and abstract science emerged and was used with remarkable (and at times, devastating) effect. This is, of course, the era of quantum mechanics or solid state physics with applications as wide as transistors, aviation, nuclear energy, telephony and so on. It created a clutch of strategic high-tech companies which needed engineer-scientists who were well-trained in this new and abstract science. Thus, science came into the engineering curriculum at MIT and then later, in other engineering colleges. Terman's article[1] on electrical engineering education at MIT provides a historical perspective.

This new, highly scientific/analytical model presupposed doubly-well-developed-ness, i.e. there are (i) basic companies which interpret societal needs and service them, and (ii) strategic high-tech companies which are innovating for future societal needs and which invest in long-term basic R&D. It is this abstract scientific model of engineering education that has been adopted and installed into our IITs. Bassett's[2] discusses the strategic role of the interaction of IITs, especially IIT Kanpur with MIT and other American universities.

Ironically enough, the only part in which there could have been some society-specific inputs was in the humanities and social sciences department. They were there in the MIT curriculum as a part of the classics tradition of all western elite education. We made these into abstract courses with foreign textbooks and little or no live societal content.

At that time, in the US, there were several engineering education/research models, e.g. the industrial model of Michigan or Delaware, the state development model of Minnesota, and so on. But we chose to copy the 'best' (Box 1).

Certainly, the doubly-well-developed-ness assumption, central to the abstract scientific MIT model does not hold here in India. So, it is essential that we examine the suitability of this model/paradigm.

The obvious question was: Who would find this new paradigm useful and how would the IITs be sustainable at all? From the government's side, this was ensured by several provisions. First, there was substantial budgetary support and autonomy, much above the norm for other existing engineering colleges. Secondly, there were a few teachers who had exposure to the West, and the number of IITs was just enough to match this small supply of teachers of abstraction. Finally, the curriculum was taught well, especially at the UG level.

The abstraction was indeed a new ingredient in the Indian engineering education system and was well appreciated by the industry and complemented their domain-specific skill-set. They looked forward to the students' entry and participation into the Indian industry.

For students, the pearly gates into the IITs were guarded by the wizard of JEE, which was an examination of simply stated questions with intricate solutions of intriguing symmetry. The curriculum extended this journey (though after a while, it got tiresome for many). Theoretical insights raced ahead of the laboratory instruments and were constrained only by one's imagination. The abstract world of charged spheres in infinite three-dimensional space, quantum oscillators, or Bessel's equations, was just the right distance from a grubby, poor and clasping society.

The urban upper class and the upper castes just loved the IITs for their access to the West, and for their monastic setting. The JEE was a hit and the brand name IIT was born. Almost from the first batch itself, going to the US was the norm for the upper half of the class. This was but a natural extension of the education that they had received. The industry got a few employees, but the dominant paradigm was to go to the US. Thus, right at the beginning, what was the 'elevator' at MIT became a 'conveyor belt' here, of escape to a richer society.

The conveyor belt was later modified. By the 1980s, the US had had enough of engineers, and the socio-economic profile of our students also changed. The 'higher education' route fell out of favour. Of course, the top students kept going to the top universities, but there were easier options for those lower down. The IT boom was just starting, which eventually created the body-shop and other commoditised engineering services jobs, and their upscale cousins – the consultancy/banking jobs (Box 2).

Box 1. Alternate paradigms

Note that there were, at that time, quite a few engineering colleges in India, some of which were following the older MIT company/sector model of close interaction with specific industries, e.g. UDCT (now UICT) in Mumbai, with the chemical engineering industry, or older still, Roorkee (now IIT-Roorkee) with the irrigation sector. Others catered to the local general society and its engineering companies, such as the College of Engineering, Pune. These colleges had a simple contract with society/industry – the supply of suitably trained engineers for socially and economically important companies and sectors.

These jobs were a reasonable compromise – they were half-way between the first world and the third, they had excellent perks, they were abstract enough to be reasonably exclusive, and mainly, they were simple enough to get for the average IITian. It is this warm-body job which continues to be the lure for the IIT aspirant.

The research agenda

There was not much visible research in the early years. If any, most was done quietly by the M Techs, who were admitted by individual departments in an exam-cum-interview with little fanfare. These unsung heroes went back into the woodworks of the Indian industry, largely forgotten and eclipsed by their prodigal cousins, the undergraduates (UGs). The UGs did B Tech projects, that were typically on topics which were the rage internationally, and which would help their application to foreign universities. That did not really count as research, for there was nothing to deliver and nobody to receive it.

However with time, the faculty and officers at the IITs wanted an elevation from a teaching institute to a research institute, much like the US universities. It was then that we first heard calls for IIT to be a 'world-class university' doing 'world-class research'. But what is to be this world-class research, who is to fund it and who is to do it?

The agenda and methodology of 'world-class research' was achieved by defining it to be measured by 'papers in international journals'. This was done officially, via faculty selection and promotion guidelines, funding for travel and so on. Of course, 'international journals' meant those from the developed world. Also obviously, the agenda and methodology of 'international journals', would be 'international', i.e. problems of relevance to the state, society and companies of the developed world.

However, for an Indian student or teacher, company or implementation agency, these journals are expensive, inaccessible and largely irrelevant. It is a deep sociological (and 'international') research problem as to why we should have decided on this particular yardstick for measuring our research. Perhaps, simply because it is easy to implement and is conveyor-friendly. Also unclear is why we did not recognize our own developmental problems as worthy of good research. Perhaps, we doubt if the 'drinking water problem' is really technical at all, and not an outcome of the endemic corruption of our common people. Or that 'drinking water' is indeed a technical problem, but it is for other 'lower' Indian institutions to address. Quite possibly, work on 'drinking water' is really an emotional or spiritual pursuit, best left outside an abstract scientific institute. Then there is also the 'enlightened' viewpoint that we all, the West and the East, have a common destiny and a common excellence. A secular pursuit of this excellence will eventually create a tide that will raise all boats. This is, of course, not borne out by the data: the disparity is increasing, and most visions of this common destiny (such as a car for every household) are unsustainable.

Anyway, our current research agenda includes subjects such as proteomics, spintronics, nanoelectronics and so on. It is unclear how these technologies will be delivered to the Indian society in any way, directly or under-the-hood. (There are a few recent exceptions, e.g. the National Centre for Photovoltaic Research and Education (NCPRE) at IIT-Bombay, but one must wait and see.) Also unclear is how we will achieve excellence in proteomics, a tool motivated by problems of a different society, of which we and our students have very little first-hand experience. In my opinion, as far as IITs matter to the common people of this country, this ducking on the definition of the research agenda remains a serious weakness.

Box 2. Warm-body jobs

In the past few years, two types of jobs seem to have gained primacy for engineers: (i) the brand-name networked jobs (e.g. management track in MNCs in India, foreign banks, consultancies), and (ii) the IT and commoditised engineering services jobs (Infosys, foreign bank IT, GM, Intel-India, and so on). Many supposedly core-sector jobs (such as Fluent, Motorola, etc.) are also fairly commoditised back-end jobs, far away from the market place and society. Both jobs need very little of the abstract scientific training that we purport to give. What they really need are (i) foremost, an ability to do easy things fast, (ii) some project management and documentation experience, and (iii) a brand-name college and its network support. These warm-body jobs are numerous, especially in multinationals. They also pay well and have many perks, such as international travel, and do not need too much hard-thinking. These jobs are, of course, a far cry from actual developed-world engineering design jobs such as designing the Airbus undercarriage (in Osaka), or dentists' chairs (in Canada), or say toothbrush making machines (in Italy). Unfortunately, these warm-body commoditised jobs seem to be at the apex of our engineering job market.

The admission process

Another big influence on our R&D is our admission process, viz. the JEE and GATE (which started around 1984). The JEE is, of course, a big disaster in the education sector in India. At an acceptance rate of 1 in 60, it is more competetive than Cornell Engineering (1 in 2), Illinois (1 in 3), Michigan (1 in 4), and Harvard (1 in 13). Compared to the IITs, all these colleges have much better and widely experienced faculty, provide much much better and well-rounded education, and are perhaps cheaper (if you factor in the coaching class fees and other costs). These reasonable acceptance ratios for the US universities actually come from a broad-basing and inclusivity of education, its objectives and its delivery. This fact seems to be lost on us. In fact, the need for exceptional 'merit' to be taught a skill so simple as engineering, is a hallmark of the elitism in our society. Another hallmark is that UNDP predicts that we will be the last society in the world (behind Burundi, Rwanda, Papua-New Guinea, the Sahel, etc.) to get rid of poverty and starvation.

The JEE is propagated by: (i) the IITs which define what an engineering education means and measure it nationally via the GATE examination, also conducted by the IITs. This leads to considerable pressure on other colleges to follow the IIT curriculum, with obvious ill-effects. For example, in the IITs, the choice of fluid mechanics II as a core subject in civil engineering reflects an ignorance that (a) much water in India is still carried by little girls on their heads, and that (b) it is largely an engineering problem (see, e.g. refs 3–5 for piped water supply, or ref. 6 for groundwater), and finally that (c) the current training does not help. Sadly, many engineering colleges end up copying such a curriculum.

(ii) MHRD, DST and AICTE which acquiese to this definition and subsidise (through huge budgetary allocations and 'research grants') the IITs to such an extent that other engineering colleges cannot afford to run any race or define an alternate engineering paradigm. Besides, there are too few good teachers of abstract engineering to copy the IITs, i.e. to teach fluid mechanics II well. Thus, these colleges flounder and the IITs remain at the top of the rankings.

(iii) A troupe of consolidated brand-name companies (Morgan Stanley, Proctor–Gamble) or high-tech, globalized, commoditised engineering companies (Infosys, Intel, GM), rather than core engineering companies for a developing nation. Their requirement for branded warm-bodies matches exactly with what the IITs supply.

This last point actually causes much damage: it creates a student body which has put in a lot of effort to get in, and sees very little additional utility in studying any further. In fact, 'rational' students spend more time in managing various programmes, building contacts and networking.

Thus, the JEE contributes to the primacy of a single viewpoint on engineering education, especially one with very few teachers able to teach it, and a pecking order in jobs in which the true engineering jobs are much lower down.

Besides this, the extreme odds cause JEE/GATE to be highly coached, thus distorting what the examination actually measures. In fact, the JEE promotes a paradoxical situation where for an aspirant to engage in amateur engineering (say, building a theodolite) actually reduces the chances of passing JEE because of the 'wasted time' in doing so. This and other competitive exams are actually polarizing school education, with devastating effects[7]. Further, the sheer number of applicants makes it impossible for IITs to do anything but have an objective-type test with numeric cut-off. This is a serious lacuna, especially for postgraduate (PG) admissions, where a more careful multi-criteria process is required.

A review

Let me come back to our stated metric of 'international research' and see how we are doing. In my opinion, badly. Our UG students never bought the international agenda. The easy, warm-body job is the primary reason why our current student joins IIT. As regards PGs, she/he too is increasingly similarly disposed. Large-scale student disinterest in academics and their preoccupation with placements, IIMs, IAS, etc. is well documented. That leaves only the Ph Ds. For all our efforts, the good Ph D student is still elusive. At first sight, there seem to be a few successful research areas, such as micro-electronics, but they usually have a multinational job dangling at the end, i.e. employers such as Intel and Motorola, who have set up cost-reduction centres in India for the commoditised research professionals that they need. None of these companies has ever designed a chip or system for deeper Indian markets.

Large private company participation in our research has still not materialized. For example, IIT-Bombay's budget for the year 2011 had a 180 crore sponsored research component, which roughly matches what it gets from MHRD. However, most (more than 85%) of this funding comes from government agencies such as DST and DBT, where there is no real notion of delivery. Sponsorships from the industry have been stagnant. Consultancy money is more difficult to interpret and its benefits to IITs are not easy to assess. In any case, most of it is routine with expected outcomes. There is not a single big achievement to talk of, either in 'blue-sky' research or in applied or mission-oriented work.

The publication count picture is also not impressive. What is more, the university of the West seems to have moved away from mere publications (see, for example, the faculty homepages of Stanford Civil and Environmental Engineering[8], and the diversity of output of individual faculty members). The university of the West is now grappling with new problems of energy security, climate change and resource use. This has created a new generation of companies and university consortiums seeking a new contract with (their view of) a globalized society. Thus, students from Western universities are studying interdisciplinarity with a new fervour and travelling to India, the Far East and into Africa, interacting with society, delivering solutions, offering discourse and influencing governments. We should not be surprised if the Government of Madhya Pradesh calls the University of Pennsylvania for advice on water-quality testing and storage, or if the Mumbai Muncipal Corporation consults the London School of Economics on a new property tax regime. Thus, just when we thought we would catch up with the publication counts, the western university has moved the goal-posts.

It may be of interest here that IIT Bombay played an important role in starting the IT and commoditised engineering services boom. Through the World Bank-funded IMPACT project of 1989, it developed curricula for other engineering colleges in IT/CS/EE and spent considerable time and effort in teaching the teachers (see ref. 9 for a copy of the World Bank Post-Project report of 1997). To my knowledge, until recently, this is perhaps the only instance when IIT Bombay actually interacted with other engineering colleges in such a systematic way. Unfortunately, the subject matter was IT/CS/EE and not civil/mechanical engineering, and the output of these colleges was to serve in the 'international' market, and not our own society. Even as late as in 2008, more than 98% of the revenue of Infosys came from abroad. Also, IBM was the largest IT service provider to India[10]. In fact, the IT boom actually diverted a huge amount of engineering talent away from core engineering and into international service. This caused the costs of international IT to come down, but also raised the costs of a domestic civil engineer, something we could ill-afford. The World Bank is now engaged with us in Project TEQIP (see ref. 11 for details and also see the embedded video). It is clear that TEQIP wishes to cement the international and sophisticated definition of engineering, rather than as an applied physical scientist negotiating with problems that we see in our immediate neighbourhood. See for example, in the reporting of NIT-Tiruchirappalli (listed in ref. 12), the topics under which their faculty went abroad for training, and also the areas of interest of faculty visitors from abroad. Many of these TEQIP colleges are located in talukas and districts with severe drinking-water stress.

Such an inverted incentive structure in the socio-economically important engineering job market has had a devastating effect on our public systems (and public finances). Many jobs in the public sector lie vacant, simply because the available talent for the given wages cannot generate the required value. Thousands of crores of rupees is spent on creating assets with poor monitoring protocols and hence of poor quality. This inversion of the engineering market place has been macro-economically observable as the service-sector growth outstrips that in manufacturing. This 'de-industrialization', especially at our low per-capita GDP levels, is alarming many economists[13,14]. In fact, most of the growth in manufacturing jobs has been in the informal sector, i.e. in unregistered workshops. Thus, while the people of India demand more 'sadak, bijli, pani', i.e. engineering services, much less is being provided. Local bridges are not built while malls flourish, water quality is awful but colour TVs abound, resources are increasingly scarce and local, electric motors lie unrepaired and hand-pumps broken. Of course, theodolites remain expensive. Ironically, another World Bank report now laments all this and recommends more civil engineering courses[15].

Politically, this breakdown of public systems is decreasing the equal access to opportunity and increasing iniquity, which are not healthy signs. If we look at the human development indices, many poor showings for India are engineering failures.

What next

So where do we go from here? In my opinion, we must go back to the basic role of the social engineer who interprets societal needs and provides solutions, i.e. the elevator model. After all, the final test of good engineering in a society is to see that societal problems are solved. If not by the state or the company, then by individuals and institutes.

Let us understand how such a change can be brought about. One may argue that much is beyond the control of the IITs, such as the warm-body coneveyor belts outpaying core engineering, but much more actually is not. IITs can and should influence most factors, especially in the long run. In any case, it will be a long process and one has to be patient. I make a list of three possible actions, at different levels of our societal hierarchy. All need substantial buy-in from our faculty and students.

Work in the public domain

Design and implement small and big projects in the public domain. There are many examples – a piped water supply scheme, redesigning of the public transport system, an energy audit for small towns. Concentrate on field-work and delivery through an engagement with local agencies. These would bring about confidence in the faculty and students and set up a context for the next task – designing new courses. Who knows, we may also win back the interest of our students in what we do.

The projects would create interdisciplinary teams across various departments, including, most importantly, the humanities and social sciences. They will create a name for IITs as regional knowledge generators and solution providers. These will also serve as illustrative case studies and vehicles of R&D, which will inform various implementation agencies.

Broaden the engineering academia

Engage in a dialogue and discussion with all engineering colleges and bring an agreement on a pedagogy and a meta-curriculum which is broad, inclusive, participative and is implementable throughout the country. Develop course materials and protocols for knowledge accumulation for local needs. Develop projects which are executable at different colleges and develop a common platform for discussing action-research. Form a team of resource persons for every course composed of academicians, experts and practitioners. Aim for a hundred good colleges and a thousand good teachers per course. Use question-wise GATE scores to measure areas of strength and weakness. By broad-basing, work towards getting the eventual acceptance ratios for IITs to about 1 in 7.

This may throw up many new and exciting courses such as 'measuring and metering' or 'design of piped water supply' or 'introduction to rural infrastructure and governance'. Welcome such courses as the definition of engineering for a developing country. Eventually, the banyan tree of 'excellent' research (sophisticated instruments, computer modelling, cutting-edge technologies, etc.) will grow on this fertile soil of a broad-based, practice-driven engineering education.

Develop within the academia: (i) mechanisms for primary work and engagement, and (ii) metrics to measure and reward innovation, creativity and research in this new engineering.

Develop a discourse

Evolve an institutional space for such engineering within the Indian polity and governance structure. Create the expectation that the taluka or district engineering college must serve as the local knowledge accumulator and solution provider. This will mean many things – have a discourse of accountability and rationality in engineering at large, and a facilitation and movement of R&D from agencies such as DST to those closer to delivery agencies, such as State Transport Corporations and Minor Irrigation, municipal councils and gram panchayats. Engage with implementation agencies and ministries to create room for entrepreneurs and innovators. Develop programmes to engage and 'embed' with governance, e.g. through internships with district collectors, specific consultancy programmes aimed at taluka and district bodies, and so on. Work to create an open and independent discourse of engineering and an independent socio-political entity called the university.

Engineering as development

Actually, all the three recommendations rely on the leadership position of IITs: it cannot be done by anyone else. The recommendations are not really as radical as they sound. Many faculty members do pursue similar goals, albeit as individuals. Institutional room for some of these changes is available in the Nayudamma Committee Report[16] of 1986, commissioned by the 'visitor' to review the IITs.

It recommended that attention be paid to extension activities, arguing that extension: (i) is essential for our country, (ii) is different from ‘international’ research and (iii) could be pedagogically exciting and throw up important research problems.

An example of such excellence in relevance is the line-up of telephone exchanges, starting with the Rural Automatic Exchange (RAX), developed by CDOT under Sam Pitroda, around 1988. The RAX was a 100-line switch which would run in the heat and dust and tumult of the Indian village. This beat the stranglehold of a few multinationals over telecom equipment, and reduced line costs worldwide to a fraction of what they were a few years before. Indians continue to enjoy the fruits of this labour (see, for example, ref. 17). This was one of the single biggest contributions of India to the developing world. Sadly, the IITs played only a small role in this story.

Indians spend more than $6 billion every year on tuition fees abroad. Each billion is enough to start a good university and run it for 5 years. Thus, the demand for a good education is indeed there and has the money to back it up. It also tells us that: (i) the IITs are not getting the best students (and most likely, not the amateur engineer), and that (ii) the western university will soon open shop here in India. The second event will mean a goodbye to elevator engineering for a long time. So it is really imperative for us to use the leadership position and goodwill of IITs while it lasts to develop a good engineering ethos and simultaneously further the national development agenda.

In fact, the Indian society is changing in many ways. The Panchayat Raj Bill has released many democratizing and developmental forces which have a distinct energy and verve. The broader society is now posing technological problems and demanding innovative, equitable and sustainable solutions. It wants an advisor and a consultant who understands and speaks for its interests and not the interests of the state machinery, multilateral agencies or corporations. And the IITs should be the ones to move forward to this challenge. Otherwise, they will be mute spectators, not only to this great Indian drama, but also to their own slow demise.

1. Terman, F. E., *Proc. IEEE*, 1976, **64**, 1399–1407. Also available at: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1454602
2. Bassett, R., *Technol. Cult.*, 2009, **50**, 783–810. Also available at: http://muse.jhu.edu/journals/tech/summary/v050/50.4.bassett.html
3. The Tadwadi–Morewadi PWSS failure analysis; www.cse.iitb.ac.in/~sohoni/svs.pdf
4. The Anjap–Sugave failure analysis; www.cse.iitb.ac.in/~sohoni/mvs.pdf
5. North Karjat Taluka rural regional PWS: a feasibility study; www.cse.iitb.ac.in/~sohoni/karjatshort.pdf
6. Groundwater information systems for regional drinking water security; http://www.gise.cse.iitb.ac.in/index.php/ground-water-mgmt-system
7. Das, J. and Zajonc, T., India shining and Bharat drowning–comparing two Indian states to the world-wide distribution in mathematics achievement. Policy Research Working Paper 4644, The World Bank, June 2008.
8. http://cee.stanford.edu/faculty/faculty_dir.html; accessed on 19 March 2012.
9. www.cse.iitb.ac.in/~sohoni/WB-IMPACT-1997.pdf; accessed on 19 March 2012.
10. Domestic outsourcing in India: Bittersweet synergy. In *The Economist*, 22 October 2009. Also at http://www.economist.com/node/14710627
11. http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:22505968~pagePK:2865106~piPK:2865128_theSitePK:223547,00.html; accessed on 19 March 2012. Alternately, enter teqip world bank in Google.
12. http://www.nitt.edu/home/icsr/teqip/, accessed on 19 March 2012.
13. Singh, A., The past, present and future of industrial policy in India. Centre for Business Research, University of Cambridge Working Paper No. 376, December 2008.
14. Ramaswamy, K. V. and Agrawal, T., Services-led growth, employment and job quality: a study of manufacturing and service-sector in urban India. In Working Paper WP-2012-007, Indira Gandhi Institute of Development Research, Mumbai, March 2012.
15. Karl, D. J., India needs a Sputnik moment. In *YaleGlobal Online*, accessed on 4 March 2011. Also at http://yaleglobal.yale.edu/content/india-needs-sputnik-moment
16. Accessed at http://www.education.nic.in/cd50years/f/G/BookG.htm in July 2011.
17. Indian mobile telecoms: happy customers, no profits. In *The Economist*, 16 June 2011. Also at http://www.economist.com/node/18836120

Milind Sohoni is in the Centre for Technology Alternatives for Rural Areas, Indian Institute of Technology–Bombay, Powai, Mumbai 400 076, India.
e-mail: sohoni@cse.iitb.ac.in