Journey of a Teacher-Engineer

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I came back to India in 1981 and joined IIT Madras as a faculty member. I wanted a telephone for my home. I had to wait for eight years in a waiting-list to get the telephone. I went to purchase a two-wheeler, a Bajaj Chetak Scooter, and paid for it; only to be told that I have been put in a queue and may have to wait for three to four years. I went to book an LPG gas cylinder for cooking; by then, I was prepared for a waiting list. When I asked the clerk at the booking counter to register for the wait-list, the old man told me, while entering my name and address, that I was unlikely to get it in my life-time, but I should still put the name as my children would benefit.

My engineer mind was perplexed – why had we got it so wrong in India. Why could we not change? I had spent six years in USA. I had not found the people there much wiser or more intelligent or more hard-working. What was wrong with us? What would be the role of an engineer in driving change?

The beginnings

I soon found out that there was no academia-industry interaction and entrepreneurs coming out of an educational institute were unheard of. Industry had very little R&D of its own and preferred to manufacture for a protected market by importing technology and know-how. Most goods were affordable only to a small section of the society.

It took me several years of struggle and experience to discover possible answers. I came to a peculiar conclusion that at times, businesses and policy-makers face constraints when driving certain services to scale. This is especially so, when a society imports technologies and products required to provide the service from an economy which has much higher purchasing capability. The products would have been designed to be affordable in that higher-income economy but not affordable for a low-affordability economy. Businesses and Policies, which would have otherwise driven the services based on these products to scale fail to do so. If the affordability gap is large, a quantum reduction in the cost of the product is required. Such quantum reduction requires disruptive innovation and when it succeeds, it makes the technology and the product way different from the original.

This learning did not come quickly and happened step by step, while I was experimenting, doing wrong things, failing but persisting.

My first Learnings

My first learning in this direction came from usage of lab-equipment for teaching at IITM. When I taught at Washington State University, a class of 50 students will have 25 (if not 50) lab kits, and the students will work in pairs (and sometime on their own) to carry out the experiments and learn. At IIT, these lab kits were imported or used imported technology, even when manufactured in India. They were quite expensive in the Indian context. So, while teaching a class of 50 even at a much-better funded IIT, only one or two experimental set-ups were available. Either the students worked in turn (each spending too little a time) or they would just watch a demonstration. I recognized that this would severely constrain learning. I wondered why these experimental set-ups and kits could not be redesigned to have much lower cost, so that 25 sets could be purchased by IITM. I took up this challenge and the first of the several kits that we designed (Fibre Optic Educator) and commercialised

reached most of the 4000 engineering colleges across India and millions of students and faculty were educated using these. Since then, I have participated in designing several other lab-kits.

One of the most gratifying experiences was when I was called by the Secretary Higher education of Gujarat to a workshop for engineering teachers in January 2015. As some urgent work kept the secretary away, I landed amongst these teachers all by myself and started interacting informally. I was surprised that most seem to know of me. When I asked how they knew me, the answer came – oh, we learned our fibre-optics using your kit. I had even forgotten about this kit by then.

Economy of Shortages

I soon recognized that this problem was not confined to education alone. Most of the products were manufactured using licensed technologies from developed nations, and were affordable to only a small section of Indian society. Industry could therefore never scale. Services provided were limited to a few and the nation lived with shortages. I recognized that products and services have to be redeveloped at price-points affordable to a larger section of Indian public. This process required transformation in products and technology. I also recognized that this could not be done by Industry alone and a strong academia-industry collaboration was required.

I started making efforts to work with industry. I used to ask them how much would that imported equipment cost? I would ask them to give me the money that would buy them one such equipment and I would not only develop the equipment, but also transfer the technology to them. Trusting me, the Chairman of WS Industries gave me ₹100,000 to build a Power Line Communication Equipment. We jumped into it with an army of B.Tech. students. I had never built anything before. But we learned. One of the senior persons from industry helped us. It took us a year and we built the first equipment. But we learned that it was one thing to build a prototype, whereas it is quite different to build something which could be manufactured, would work 24X7 without failing, and also be a commercial success. We learned more from industry personnel than they learned from us. The system was never designed by us such that it could be commercialised. But WS placed our prototype in a display case, invited their international business partner and could bargain a 50% cost-reduction.

The word went around industries and I started getting calls to repair some imported equipment and build some small ones. My students, inspired by our success, plunged into each such opportunity. A surprising thing was that I was not just teaching them, but started learning from my students. Over time, I have found **learning from younger colleagues and students** is the best way to keep oneself abreast with technology. Technology changes rapidly. Continuous learning is the only way. I find many senior engineers learn primarily from vendors and from a bit of reading. This is not enough. Learning form youngsters who build things adds up and makes one innovative.

Taking Risks and Entrepreneurship

As we took up development of lower-cost products, we recognised that Indian industry not only had very little internal R&D, but was somewhat risk-averse. To introduce new products to the market, a different approach was needed. We discovered Start-ups and Entrepreneurship in the Indian context to bridge this gap. We started incubating companies somewhat informally in the beginning, as Indian Academia did not encourage start-ups in 80’s and 90’s. Questions used to be raised whether the educational institutes were to purse “Saraswati” or “Lakshmi.” This however did not deter us, as we considered this the best way to translate technologies developed.

As mentioned earlier, India was struggling to install new telephones in India with waiting list as long as eight years. At the same time, telephones were no longer considered a luxury, but something that brought in work-efficiency and was a tool for development. Getting telephones to every village was considered equally important. We first thought that it was lack of technology which was preventing this. But by the early nineties, we started looking into the economics of telephony and costs involved in each element. We came to the conclusion that telephones in India could reach no more than 4% of

Indian homes at the prevailing capital and operational costs. These costs had to be brought down by a factor of four for the telephone to get to 50% of Indian homes. As costs of other elements involved in the electronic telephone network were going down due to Moore's Law, the copper based local loop was dominating the total cost per line. The only solution was to replace the copper local loop with wireless. Wireless was however relatively expensive at the time. But we recognised that we were replacing copper with electronics. Recognizing that Moore's law was on our side and a programmable architecture will help us bring down costs, our team consisting of a start-up and IIT R&D team, took the challenge to build a system and deliver by 1995 a solution. They designed a DSP based Wireless in local loop called corDECT WiLL. It brought down the costs of installing a telephone line by a factor of four and about a million lines were installed. This triggered the bringing down the price of mobile telephony and the cost-constraint was broken. From 7 million telephone lines when we started this development, India has grown today to 950 million telephones today.

Building a delivery team

The task of building Wireless in Local Loop was indeed a very challenging task. Fortunately, there were three of us amongst faculty at IITM, who were committed and knew the basics of what was to be done. With expertise in different disciplines, we had learnt the difficult art of working together. But we needed experienced industry personnel too, who can convert our ideas into products. We made a list of some 8 alumni of ours, who were working in different industries in India. We decided to travel and meet them to sell our dream of 100 million wireless phones (to begin with we could not envisage anything more) in India. If we could get 5 of them, we would start the effort. Fortunately, all eight of them quit their jobs and joined us, not knowing where their salaries would come from. Now we needed the funding as well as support of department of telecom to help us define specifications and carry out pilots. We decided not to go to Government for financial support. Instead we sold the dream to industry to support the development. We went to the Government only for defining specifications and for pilot-deployment. Having tied up all this, we needed a somewhat larger team. Students at IITM for the most part were inclined to go abroad for higher studies at that time. We had learnt that many young engineering graduates from tier-2 colleges were bright, even though they may not have got adequate undergraduate education. Once inspired, they were capable of working very hard and make up for their weak background. They would then deliver the impossible. We had done it and had learnt that an army of **inspired young men and women with proper guidance is the best resource that we in India have**. We just needed to identify them and build them up. They have never failed us. It is with such a team that we took up the challenge and built corDECT WiLL in two years, at the price target that we had set. We had set the stage for wireless to take off in the nation.

Once the industry-academia collaboration coupled with youngsters succeeded, the formula could be replicated to translate technology in many spheres and make a difference to lives of less-privileged people in India.

Proliferation of Start-ups

India has 600,000 villages and most did not even have a telephone line in 90's. CorDECT WiLL was used by a start-up to help setup a telephone and Internet kiosk in a village like an operator-assisted Public call office, except that it supported Internet service in addition to a telephone. A large number of services were provided to the villagers using this. Telemedicine was used to connect village folks to a city doctor. A telemedicine kit was developed by another start-up, which allowed a doctor to measure temperature, blood-pressure and ECG of the patients remotely. Internet was used to provide remote education by yet another start-up. A program was created to support the farmer in early identification of crop diseases using pictures transmitted over the Internet and providing timely advice for remedy. A whole host of Government services was provided on the Internet. This was carried out in 2001, when Internet was still in its early phase and data communication was yet to be supported on mobiles.

The successful translation of innovative technologies developed by IITM working with multiple start-ups, was the basis of changing the minds in academia. Saraswati and Lakshmi were recognised to work in tandem to strengthen technical institutions. We helped IITM formulate the first set of processes for setting up incubators in an institute. This started getting replicated throughout the country, with Department of Science and Technology taking an initiative to create incubators in various educational institutions. At IIT Madras, it took us time to set up formal incubators. But once they were set-up, start-ups happened fast. Till date, I have personally incubated **almost 100 companies**. A large number of technologies and products have been developed as a result. We founded IITM Incubation Cell and Rural Technology and Business Incubator (RTBI) and subsequently a Bio-incubator and Med-tech incubator at IITM.

These Incubators accelerated technology development and translational work. RTBI was focused on incubating companies providing products, services and employment in rural India. It was instrumental in setting up India's first rural BPO, so as to create livelihood in rural areas. Several companies looked at outsourcing production to Rural India. We developed an ATM machine, at a cost of 20% of what was available in the market, so that financial services could reach different parts of the country. Recognising that we were dealing with semi-literate people, when we worked in rural India, we decided to focus on using local language voice-based communication for all kinds of transactions. But voice recognition and text-to-speech were not available in local languages, and whatever recognition existed, gave a large number of errors. But a start-up specialised in ensuring reliable services in the presence of these errors. The technology was used in the financial domain, with farmers in agriculture, and for "conversations" with mothers in a mother-and child health care program. The academia start-up combination often enabled what was otherwise considered impossible.

Industry – Academia Connect and Research Parks

In 2004, I joined the board of SBI, the largest bank in India and IDRBT, a technology subsidiary of Reserve Bank of India. I found that technology can make a major difference in banking and financial systems. We computed the costs incurred by a bank when one goes and makes a deposit or withdraws money. If no technology was involved, it would amount to about ₹250 per transaction today. Half of it had to do with cash-teller (front-end), whereas the other half involved handling of accounts (back-end). Computers and communications connecting all the branches could significantly reduce the latter and could enable anywhere banking. ATMs, Internet banking and mobile banking could largely eliminate the former and introduce any-time banking. It appeared to be an impossible task in India to get all this done in India. But hard work and perseverance has moved the country. Not only anytime anywhere banking has become possible today, but a transaction involving Internet banking or Mobile banking costs a bank only between ₹2 to ₹3 per transaction and that involving ATM costs about ₹15. It was especially important in a country with large population and where most transaction amounts are very small. Later we helped create Mobile Payment Forum of India and were instrumental in defining the person-to-person mobile payment process, irrespective of their mobile operators, their banks and the technology providers. Mobile wallets and mobile payments are changing the country and bringing forth revolutions in sectors such as transport (Ola and Uber) and retail purchases. When the problem of frauds in credit-card transaction was brought to our notice, we came up with the idea of sending an SMS as soon as a transaction is carried out. It significantly reduces frauds and India may be the only country where this is adopted by all bankers.

Our work in financial sector reinforced the value of industry - academia interaction. The problem is that Academia believes that Industry is not interested in working with them and only wants to import technology. On the other hand, Industry believes that Academia is too focused on publishing papers and cannot help them develop technologies which can be taken to the market. There are truths in both these sentiments, but they are partial truths. If prejudices are left aside and both learn from each other, wonders are possible. In fact, a combination of Academia, experienced industry persons and enthusiastic youngsters possibly defines the best Innovation eco-system today. After experimenting with this multiple times, we decided to formally enable it by setting up a Research Park, adjacent to

IIT Madras. IITM already had excellent faculty and bright youngsters. We needed to bring industry into the eco-system. Industry would be invited to set-up their R&D centers at the Research Park. However, the rental contract with industry would include an obligation for industry to work on R&D with IITM and earn certain amount of credits. The industry-auditors would then insist that joint R&D and earning credits become the responsibility of someone and impact their variable salary. These people will then do their utmost to work with IIT. Proximity and obligation would enable breaking of barriers; once they start working together and get some success, nothing will stop either of them. IITM Research Park (IITMRP) started operations in 2011 with 400,000 sq.ft of built-up space. It houses about 60 R&D centers of Industries, working closely with IITM. The incubators and incubated companies are also located at IITMRP. The Park has now been expanded to 1.2 million sft and over the next two years, the number of R&D companies in the park is likely to touch 200.

The Next Frontier

About three years back, we turned our attention to the chronic power-problems of India; huge power-cuts and large percentage of homes unconnected to the power-grid and significant section of people's inability to pay for even below-cost tariff. We needed a technological breakthrough, just as wireless was in telecom. We had little expertise in this area. But rather than simply complaining, we decided to learn and attempt to make a difference. Our formulae of leaning from youngsters and colleagues helped us once again. We started looking at how a simple Indian home could get some power from a roof-top solar panel to power at least some lights, fans and electronics items. We started with a small size (125 Watts) low cost (₹5000) solar panel. We were perplexed by what we learnt. While the solar panel gave us varying electrical power through the day, we found that 15% or more would be lost when we convert this DC power to AC power and synchronise to the grid. We tried to get better converters, but even at very high cost (disproportional to that of solar panel), the losses would not be below 10%. We were then told that another AC to DC converter will be needed to charge the battery from the combined solar and grid power and yet another DC to AC converter when power is drawn from battery to power load. Each of these converters would have similar losses. Then there will be battery losses (10% for Lead Acid batteries). In other words, 55% or more solar power would be lost before it reaches the load. There was no answer to my query why we are wasting expensive solar power. It was then pointed out to me that loads are becoming all DC needing DC power input. I knew all electronics needed AC-DC converters. But so do LED lights and the fan's Brushless DC motors (which saves over 50% power as compared to AC-motor based fans). All this made no sense. We therefore came up with the Solar-DC concept, departed from conventional wisdom, and introduced a DC power line for homes. Solar will power the line directly and so will be the battery. Loads will be DC powered. Only the grid-input will be converted from AC to DC. Of course, it involved complicated design to get this done minimising the losses. But far more difficult was to overcome the mind-set which had settled this issue over a century back and considered AC power-line as the only future. Technology development was only one task. But there were no manufacturers and no standards. We had to create a standard, develop the technologies required, and commercialized them and carried out pilot deployments in a significant number of homes in multiple cities and villages. Slowly the tide is turning. DC power-line at home and offices and DC-powered appliances will bring in sustainability and make solar energy the norm. May be India can get 50% of its power from solar by 2030.

We now work on electric vehicles. That is another frontier to capture. India's growing pollution and its forever dependence on imported oil will not go without it. By 2030, India can have all its transport running on electricity. While conventional power can charge the vehicles in the night time, solar power will do so in day time. Technology and Policy can enable this. We have to have faith in ourselves. An Engineering mind must be humble, committed to sustainability, in tune with human values and believe that "nothing is impossible."