Innovation for a Better India

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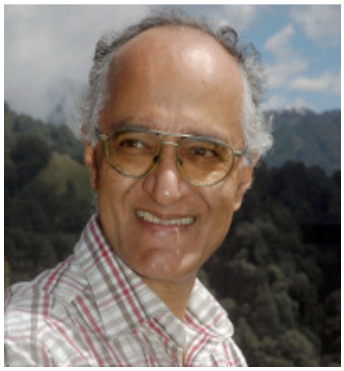

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1 Introduction

The Internet has changed the world. In the short span (historically) of 50 years, it has transformed the way in which billions of us work, socialise, get entertainment, and conduct our personal and work lives. Even the billions who do not directly use the Internet are affected by the globalisation that the Internet has made possible. Two key factors in this remarkable transformation are the World-Wide Web (WWW) and the search engine.

The World-Wide Web was invented by Tim Berners-Lee, a scientist working in the CERN labs in Geneva [Wiki 12]. He needed to collaborate with a group of scientists in different places. Typically, they exchanged information and documents via the nascent Internet using email and FTP. This was tedious. Email requires that the author sends the document, and that the recipient saves the document. Thereafter, there are multiple copies of the document that may not be consistent with one another – when the original author changes the document, the recipient's version becomes obsolete. FTP requires the recipient to know the exact location, filename and format of each document and to have a login account in every computer.

WWW greatly simplifies this task. The documents are connected to one another via URLs (links) and accessed by a browser that finds and retrieves each document when it is required. Underlying this simple user experience is an array of technologies: electronic storage of documents, indexes and cross-references in documents, HTTP/TCP/IP, HTML, FTP, etc. Berners-Lee did not invent most of these. His contribution was to combine them in an unusual way to serve a burning need. This is *innovation* at its best.

The Internet is not the only radical change in our lives in modern India. One example: until the 1970s, the small urban middle and upper classes used shampoo, then available in bottles

costing Rs. 50 and upwards (equivalent to paying Rs. 500 or more today). The vast majority of Indians, especially those in rural areas, did not use shampoo. There were many reasons: Rs. 50 was a large investment for most Indians; the shampoo in the bottle could easily be adulterated; during use, if it spilt, several months of hair-washing could go down the drain. People preferred to buy soap or powders costing a rupee or two. The shampoo market was dominated by Hindustan Lever which was making a comfortable profit with its urban-based distributor network selling to the upper classes.

Along came CavinKare with a unique business plan [Munshi 09]. They packaged shampoo in small sealed plastic sachets, set up a large distributor network throughout the country to sell shampoo at Re 1 per sachet. Even a poor person in a remote village could now use shampoo occasionally when s/he had Re 1 to spare. As the packet was sealed, there was no question of adulteration. Their Chik shampoo sachets rapidly gained popularity among the rural people. Today, CavinKare has 25% of the shampoo market and sachets account for 70% of the shampoo market.

Again, this innovation used existing business practices and technologies. It put them together in a novel way to create and capture a vast new market. *While bottled shampoo was profitable due to high margins on small volumes, sachet shampoo was profitable despite very small profit margins because of very high volumes.*

As engineers, we dream of being responsible for the next disruptive innovation. What is innovation, why is it important to India, how can we be more innovative, can innovation be taught? These are questions that we address in the rest of this paper.

2 What is Innovation?

Creativity and innovation are related but distinct. *Creativity is coming up with something novel and non-obvious*. This may include a new theory to explain observed facts, writing a book or poem, composing music, and inventing technical mechanisms.

Innovation is putting ideas to use in a novel way for the benefit of society. Two key differences: innovation may make use of existing ideas while creativity involves new ideas. Innovation must be useful, while creativity need not result in any immediate benefit to anyone.

3 Why is Innovation Important?

India faces vast and seemingly insurmountable problems. These include lack of affordable housing, clean water, sanitation, basic health facilities, good schools and colleges, and many more for the majority of Indians. The 70% who live in rural India are especially badly off. While our cities score better on many of these parameters, they are bursting at the seams and affordability is a problem for the many slum dwellers.

With the advent of TV and ubiquitous telecommunications, the poor are no longer willing to accept their lot as “fate”. Thwarted aspirations often lead to social unrest and violence. Besides, a country cannot claim to be a mature democracy unless there is a measure of equality in the quality of life of its citizens.

India is a country of contrasts. Consider per capita income [WorldBank 12]. The family income of the top 250 million people is about Rs. 19 lakhs/year[1]. This is quite generous by any standards. The middle 500 million people have a family income of about Rs. 6

[1] Considering an exchange rate of Rs. 50 per $1 and a family size of 5. The figures quoted are averages. Within each group there is obviously a range of income.

lakhs/year. This enables a comfortable middle-class lifestyle. However, at the bottom of the pyramid we have 125 million people who subsist on Rs. 75 per day which is at best adequate for the bare necessities of existence.

To address these inequalities, large-scale redistribution of income is not politically feasible. Bringing the poor up to middle-class standards requires growth in national income. Much of this increase in national income will be absorbed by the well-off. Hence, to achieve decent living standards for all in a few years requires continuing growth at a high rate of 10% per annum or more. Of course, growth must be tempered by measures to ensure a reasonable degree of equality.

India's remarkable growth over the past 2-3 decades has been driven primarily by manufacturing and services. These can result in only a linear rate of growth. If the investment in a factory is doubled, it typically results in double the output. Likewise, if an IT company increases its workforce by 50%, its revenues increase by about 50% also. In fact, this has been largely how our successful IT companies – Infosys, Wipro, IBM and others – have achieved their spectacular growth. They have each increased their headcount from a few thousand to 1-2 lakhs.

Product design and innovation promises much higher growth rates. For example, the Google search engine patent was based mainly on the work on 2 graduate students done over a few years. It has earned over $330m (Rs. 1,600 crores) in royalties for Stanford University [Chao 06]. Another example: for every cellphone sold in India, an amount of between 2-15% of the price is paid as royalty to the developers of various parts of the cellphone [Jhun 11]. These designers did their work a few years ago, and now collect huge amounts of royalties every year with practically no effort. Most of this royalty flows outside India, though this is changing gradually.

Innovation is needed for another reason. A modern lifestyle consumes a lot of irreplaceable natural resources and generates considerable pollution. The ratio of per-capita consumption of resources of the average Indian to that of the average person in the US is about 1:20. Comparing rural India to urban India, again the ratio is about 1:20. If India's 1.25 billion people consume resources at the rate of the 100 million affluent urban Indians, or the 250 million affluent in the US, there will be an environmental disaster. As a democracy, we cannot prevent rural India from developing. *Innovative solutions that are environmentally sustainable are crucial for India's development.*

4 The Roads to Innovation

Is innovativeness innate, or can it be cultivated? Research and experience indicate that there are factors that encourage innovation. We first give a very simplified view of how the human brain works. Next, we describe some of the factors favouring innovation.

4.1 The Human Cognitive Process

The human brain has a memory consisting billions of neurons. Each neuron can hold a fact or other piece of knowledge. An idea occurs when a number of these facts are connected together. Connections occur when neurons emit signals that flow to other neurons through synapses. There is some randomness in the paths taken by the signals. Thus, with a given set of facts, different networks of neurons, i.e. different ideas, may emerge. Ideas may emerge from a combination of apparently unrelated facts (serendipity). The firing of neurons occurs both when we are awake and when we are asleep.

4.2 Factors Favouring Innovation

This view of the human brain appears to suggest a simple recipe to foster innovation: fill your brain with facts, train your neurons to fire, and be prepared to recognize which patterns are useful ones.

Can innovation be fostered so simply? We examine this question in more detail below. This draws heavily on the excellent book by Steve Johnson [Johnson 10]. Johnson describes 7 factors, devoting one chapter to each. We classify these factors into three: those that depend on the *domain* of the problem, those that are the influence of the *external* world, and those that are *internal* to the innovator.

4.2.1 Domain Factors

The Adjacent Possible: The essence of engineering is building on the work of others. The vast majority of innovations require a set of pre-conditions to be successful. Innovation is the art of having the right idea in the right time and place. Consider the invention of the World-wide Web (WWW) by Tim Berners-Lee in CERN, Geneva in 1989. This was based on several ingredients: a large corpus of digital documents; a ubiquitous, reliable network with many users; indexing and cross-referencing used in printed books coupled with hypertext for including these in digital documents; standard encoding of digital text (ASCII); and standard protocols for transfer of files across a network (FTP). In addition, Berners-Lee had the problem of collaborating with scientific colleagues in geographically remote labs. Combining these ideas, Berners-Lee invented HTML, HTTP and WWW to solve the problem of accessing the corpus of documents produced by members of his distributed team.

Suppose Berners-Lee had conceived the idea of WWW in 1979? At that time: networks were fragmented and had few users; diverse encoding formats were used for digital documents; many operating systems had incompatible file formats and even incompatible names for file. WWW in 1979 might have run on a few computers, but most people would have continued to rely on printed documents. WWW in 1979 would have flopped. Successful innovation is usually an incremental advance on existing technologies. Radically new *creative* ideas are rarely converted immediately into useful innovations.

Exaptation: Coined by Stephen Jay Gould and Elisabeth Vrba in 1971, *exaptation* refers to something designed for one purpose but used for another quite unrelated purpose [Gould 82]. Eg. Gutenberg used the screw press for printing text on paper. This was a mature technology used for wine-making in the Rhineland.

A contemporary example is the SMS. This was originally invented as a convenient way for operators to download short service messages to subscribers, using some unused “free” bandwidth during a cellphone voice call. SMS has now become an important means of communication between subscribers, for advertisement, etc. It is a revenue-earner, in some cases earning more revenue for the operator than voice calls.

4.2.2 External Factors

Networking: In 2008, Geoffrey West and his team at the Sante Fe Institute studied the quantity of infrastructure in different cities across the world. They found that the infrastructure needs of a city grow much more slowly that the population. The growth was found to be proportional to the population raised to the power -1/4. I.e., a city 10 times larger requires only 1.77 times increase in roads, a city with 1,000 times the population requires only about 5.6 times the roads. However, when they considered innovation, they found that while a power law holds, the exponent is positive. Thus, a city that has *10 times larger population is 17 times more innovative.*

Why does this happen? Interaction with others in formal and informal settings has two effects. One, when we expose our ideas or the problems we are working on, the questions and comments by others may lead us to rethink our solutions. Second, when we are exposed to the

ideas of others, even in very different areas, this may give us new insights into our own problems. Networking is much more powerful when the people in the network are passionate and creative. Thus certain areas have been extremely innovative – Silicon Valley encompassing Berkeley, San Francisco, San Jose and many cities within a span of 100 km, and Route 128 in a radius of 50 km around Boston and Cambridge are two renowned hotbeds of innovation. Other large metropolitan areas have not been so successful, such as Pittsburgh despite the presence in it of the world-renowned Carnegie Mellon University.

Table 1: Hypothetical rate of innovations in 3 Indian cities

City	Mandi	Chandigarh	Delhi
Population	0.5 lakhs	10 lakhs	110 lakhs
Innovation rate	1	42	847

Table 1 gives hypothetical rates of innovation in 3 Indian cities, based on West's findings. Do we conclude that we need to live in a large metropolitan area to be innovative? This would be bad news for IIT Mandi! Fortunately, telecommunications and the Internet have greatly reduced the barriers to communication in today's world. Skype, Facebook, email, WWW and inexpensive POTS (plain old telephone service) reaching almost everywhere have made it possible to build up networks of people with whom one exchanges ideas regardless of distance. Note that the choice of people in your network is important. Johnson writes: "*This is not the wisdom of the crowd, but the wisdom of someone in the crowd. It's not that the network itself is smart; it is that the individuals get smarter because they are connected to the network.*"

4.2.3 Internal Factors

Serendipity: Sometimes, when trying to solve a difficult problem we reach a dead-end, unable to make progress. Suddenly, out of the blue, while we are engaged in something quite different, the solution emerges. This is *serendipity*.

The classic example is the discovery of the ring structure of benzene by the German chemist Kekulé von Stradonitz in 1865. He had been struggling with this question since 1855. One day, while daydreaming in his living room before a crackling fire, he had a vision in the flames of Ouroboros, the mythical Greek serpent that eats its own tail. This gave him the insight that benzene consists of a ring of 6 carbon atoms, opening up the field of organic chemistry that has profoundly changed human existence through a myriad of useful compounds.

Slow Hunch: An idea does not always get developed into an innovation by working on it over a short time. The idea may be ahead of its time such as the hypothetical example of WWW in 1979. At the time we have the idea, we may lack knowledge or experiences necessary to convert it into something useful. After the idea remains in the back of our mind perhaps for years, we may realise that its time has come and we are able to work it out to its full potential. The seed germinates slowly then when conditions are right, suddenly sprouts and grows rapidly into an innovation.

During his boyhood, the 18th century scientist Joseph Priestley liked to trap spiders in glass jars. He had a hunch that there was some deeper reason why they perished if the jar was sealed. Twenty years later, this hunch resurfaced when he devised an experiment with a sprig of mint in a jar that showed that plants produce oxygen.

Note: Johnson's book elaborates on these factors leading to innovation. [Johnson 10] He covers two more factors, *platforms* and *error* that we classify as domain and internal factors respectively.

5 Cultivating Innovation

The first step towards having innovative ideas is to fill your brain with as many facts as possible. To this end, read widely within your discipline and interests and even outside these. Apart from the courses in your discipline, take some courses that are quite unrelated to your future profession. You never know when these will become useful, perhaps many years down the road. Academic institutions give you the opportunity to attend seminars on a variety of topics. Again, make it a point to attend seemingly "irrelevant" seminars. While reading and attending seminars, think about what you read and hear, make notes on what you have learnt. This effort "cements" the facts into your neurons, triggers neurons to fire and helps result in useful new ideas.

Last but not least, exploit the power of networking. Develop a network of thoughtful, intelligent people with whom you can interact in person, by email, by social networking. Some of these may be in your current core interest area, many should be in diverse fields. Bounce your ideas off them, listen and comment on their ideas however fanciful and unrelated to your core interests. Miller describes innovation conversations as an important part of the innovation process [Miller 07].

6 The Final Word

India is a country with vast problems, arguably the most fertile place in the world for a budding young engineer or scientist looking for challenges. Innovation is the key to the well-being for all India's citizenry through equitable, sustainable growth. Innovation can be cultivated by any bright young engineer. While solving key problems of the nation, you will achieve immense self-satisfaction, probably great financial rewards and possibly widespread fame. The exhortation of John F. Kennedy "Ask not what your country can do for you, ask what you can do for your country" is not a call to sacrifice and suffering, but an invitation to a rich professional career!

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