COMMENTARY

Indian science slows down: The decline of open-ended research

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While fears that the total R&D capability of the country has not grown commensurately in recent years has been recognized and expressed, what has been overlooked is that open-ended research has also been in relentless decline.

Lies, damned lies, and statistics

There is no dearth of submissions about the decline of quality science in India[1] and of falling standards of research in India[2]. 'The quality of research,' bemoans Chopra[1], 'hardly seems to concern anybody in our country'. Chopra also wonders, 'Why are we more concerned about the quantity of our S&T rather than the quality?'

Lost in this debate is the reality that what passes off for research through our S&T funding mechanisms is mainly of the strategically targetted type, with the open-ended variety in steady decline. The decline that is talked about[3] is mainly due to this neglect.

Recently, Jayant Narlikar[4] compiled his list of what are arguably the top ten achievements of the twentieth century in India. In a roughly chronological order, he ranks them as follows:

(i) Srinivasa Ramanujan, discovered by the Cambridge mathematician G. H. Hardy, whose great mathematical findings were beginning to be appreciated from 1915 to 1919. His achievements were to be fully understood much later, well after his untimely death in 1920. For example, his work on highly composite numbers (numbers with a large number of factors) started a whole new line of investigations in the theory of such numbers.

(ii) Meghnad Saha's ionization equation (c. 1920), which opened the door to stellar astrophysics.

(iii) S. N. Bose's work on particle statistics (c. 1922), which clarified the behaviour of photons (the particles of light in an enclosure) and opened the door to new ideas on statistics of microsystems that obey the rules of quantum theory.

(iv) C. V. Raman's discovery that molecules scatter light (c. 1928), which became known as the Raman effect. It is used to study the internal structure of molecules.

(v) G. N. Ramachandran's work in biology (c. mid-1950s), for which he is considered one of the founders of the rapidly developing field of molecular biophysics.

(vi) The Atomic Energy Commission's development of atomic energy power and nuclear capability through a dedicated programme (founded in the 1950s).

(vii) The Green Revolution in agriculture (the 1960s and 1970s).

(viii) Development of space programme and satellite fabrication/launching capability (from the late 1970s).

(ix) Work in the various laboratories on high-temperature superconductivity (since the late 1980s).

(x) Progress towards transforming the Council of Scientific and Industrial Research laboratories' orientation from workbench research to industry and the marketplace (since the late 1990s).

What Narlikar sees as achievements, I see as an unfolding tragedy of S&T in India, the unintended consequence of our S&T policy. In Narlikar's list, we see that before 1950, we had names like Ramanujan, Saha, Bose, Raman and Ramachandran, but in the latter half of the twentieth century, we have had only 'great agencies for the successful applications of known technology' (R. Kochhar, quoted from personal recollection). In fact, in an S&T budget of about Rs 15,000 crore, may be less than Rs 500 crore goes every year to open-ended research.

What is to be made of the artificial distinction between basic and applied research? Again, from personal recollection, the words of the Indian scientist, C. N. R. Rao are perspicacious: 'There's no such thing as basic research and applied research. There is research that is applied, and there is research that is waiting to be applied'.

It will therefore be meaningful here to draw the distinction, not between basic and applied work, but between the open-ended type and the strategically-targetted type. In the open-ended category, I will include all activities which are variously described as basic research, concept-driven research, investigator-initiated research, opportunity-based research, wish-based research, curiosity-driven research, blue-sky research, and so on. In the strategically-targetted basket, I will group all S&T activities that are of the nature of applied research, goal-directed research, need-based research and mission-oriented research. This is what our research agencies like the CSIR, BARC, ISRO, DRDO, ICAR (the mega-organizations of Varkey[2]) are mandated to do.

Contrary to Varkey's conclusion[2] that 'India's scientific manpower is large in number', it is clear to me that India is not deploying enough scientific manpower. Not only is there a decline in the 'number of scientific research publications from scientists in India', as pointed out by our Prime Minister A. B. Vajpayee, there is also 'an alarming decline in the number of students seeking a career in scientific research', a point made by the Deputy Prime Minister nearly a year ago (quoted from a speech by L. K. Advani on 4 May 2003 at Bangalore). This bodes ill for the country, especially considering that presently, the number of R&D scientists/engineers we have as a proportion of our population is estimated to be around 157/million, which is 1/50th of the corresponding figure for South Korea and about 1/30th of that for USA or Japan. In fact the OECD benchmark is that we should have 0.5% of the work-force engaged directly in R&D activities. This will mean that we should have about 2 million R&D workers, and not the 157,000 that we have now. We need, just on quantitative terms, to step up the number of R&D workers by a factor of 12, in a scenario where we see only a relentless decline in the quantity and quality of manpower we are training to do science and engineering.

In all this, the quality of research has also suffered. In sheer volume, because of our huge size (1/6th, i.e. 17% of humanity), we rank #13 for citations and #21 for papers among the 149 top-performing countries in all fields of science, technology and medicine. But when we introduce a measure for quality, say the number of citations per paper, we quickly drop in rank to #119. Another way of stating that on a per-capita basis we are doing poorly is to compare our scientific output, which works out to 20 papers/million people for India, with that of one of the leading scientific nations, the 1000 papers/million people for USA. To catch up with this performance, we need to increase our scientific effort 50-fold. The inevitable conclusion from this is that we do not have enough research institutes in our country doing open-ended research; we may need 50 times as many as we have currently just to reach the US benchmark for the number of papers per million of population. If we switch our attention to the number of patents disclosed per million of population, we cut a much sorrier figure by clocking at the rate of 1 patent per million, and this is 1/300th of USA's and 1/1000th of Japan's. Our R&D expenditure per capita is 1/100th of South Korea's. All this grossly sub-critical effort is responsible for our under-achievement as seen in our share of global R&D output, which is only 1.58% (cf. India's 17% of global population).

In defence of open-ended research

Let me now make my case for open-ended research. One of the great revolutions taking place all over the world, and in the country, is about how the optical-fibre network has transformed, how economies are using information and communications technology. In India alone, projections are that about 500,000 km of optical fibre cables will have been laid across the country. However, no one notices that the optical fibre cable was invented by an Indian. He remains one of the few great unsung heroes of the last century. I am talking of Narinder Singh Kapany, described often as the Father of fibre optics, who invented the glass fibre with cladding in the early fifties. This is one of the supreme examples of purely wish-based open-ended research that goes on to feed a multi-billion dollar industry.

It was a series of unplanned accidents that created the modern fibre-optics revolution. By the early 1950s, many American researchers were successful in demonstrating that it was possible to transmit an image through a bundle of fibres. Around 1953, Kapany developed fibres with cladding, thus greatly improving the transmission characteristics[5]. Even then, they could carry light only a few metres (now we talk of networks of half a million kilometres and such a possibility would have been unimaginable, let alone projected in a mission-mode). The first use was to probe inside the body. Even Narinder Kapany never thought that he was going to set in motion a billion-dollar industry, the fibre-optics communications revolution.

By itself, the optical fibre was not of much use as a communications device. For this, another invention had to join it in the river of S&T. This was the invention of the laser, in 1960 by Theodore Maiman. Such is the lack of foresight in the mission-oriented or strategically-targetted mode of operation that lawyers at Bell Labs were initially unwilling to apply for a patent on the invention of the laser, believing that it had no possible relevance to the telephone industry. Together with fibre optics, the laser has today revolutionized the telephone business. In fact, this was history repeating itself. In 1876, Western Union, which was then the largest telegraph company, had a chance to buy Bell's telephone patent for a small sum. Instead, typical of their tunnel vision, and thinking long-term, as such planners arrogantly think that only they are capable of doing so they decided to stay out of the telephone business as long as Bell stayed out of telegraphy[6].

History is replete with such instances, where panjandrums charged with the responsibility of conducting strategically targetted activities fail to see what is possible where the sum is greater than the parts. This is particularly true when the whole results from 'the collected flow of all the tributary streams', while the parts are created as springs that feed the tributary streams and usually originate in an open-ended effort. In William Whewell's metaphor of a river, the mighty stream of S&T accumulates from the thousands of springs and streams of open-ended S&T. It is clear that we are doing too little of this variety of research since Independence, and we are not inventing enough of these springs and streams to be capable of technology leadership on a global scale.

Thus, the men we celebrate today are mission-mode managers, institution-builders, network-managers and system-integrators, and the would-be giants of science (the Sahas and the Ramans) have now withered away under these great banyan trees of the mega-organizations performing strategically targetted S&T.

I end this brief for open-ended research with two apposite quotations:

> *'No one travels so high as he who does not know where he is going'*
> – Oliver Cromwell
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> *'The farther you go, the less you know'*
> –Lao Tse

1. Chopra, K. L., *Curr. Sci.*, 2004, **86**, 497.
2. Varkey, M. J., *Curr. Sci.*, 2004, **86**, 500.
3. Arunachalam, S., *Curr. Sci.*, 2002, **85**, 1391–1392.
4. Narlikar, J., *The Scientific Edge*, Penguin Books, 2003.
5. *Business Week*, 6 March 1995.
6. Rosenberg, N., Uncertainty and Technological Change. June 1996, quoted in *The Economist*, 28 September 1996.

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