

Science education in India – time to leapfrog with caution

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There is a dire need to expand the scope for higher science education and research in the country to reach its goal of a knowledge power in the globe. Government agencies are announcing a massive increase in the number of such institutions on a daily basis. It is not, however, clear as to how we will get the adequate qualified human resource to man and run these new institutions bearing brand names of repute or fill in the existing vacancies. This article attempts to review the current situation and strategies planned. The bottom line is to provide an attractive career in terms of monetary benefits as well as working environment. In the meanwhile, should we not hasten carefully, if not slowly?

Keywords: Expansion, human resource, research, science, teaching.

INDIA has been able to break the shackles of the image of an impoverished society, thanks to the evolution of knowledge-based information and communication technologies, as well as successes in defence and satellite technologies. This has created the image of a potential knowledge society for the country in the world community and there is indeed a new interest in India as an investment and outsourcing destination. Striking advances in medicine at the high end have led to India being a destination for affordable, sophisticated medical treatment. India is also recognized as an emerging important player in biotechnology. At the same time, the country occupies a low ranking in human development index and faces challenges to make it an inclusive society. It is obvious that science and technology (S&T) has played an important role in India's transformation and will be a key component in bridging the two Indias, one representing a knowledge society and another, a society ridden with poverty and deprivation.

Is India slipping down in science?

With this background, there is a concern that India is slipping down in science education and research. Since the total population is over a billion, India is still able to harvest a segment of intellectuals that can hold forte, despite concerns of falling standards of science education and research. That is how the country is able to create the image of a knowledge society, boosted by an impressive

performance by the NRIs in their country of adoption. But, we need to worry about the actual ground reality.

Enrolment and completion data

A look at the actual numbers would help to understand the situation. There are two caveats to using the statistics available to draw conclusions. (i) The numbers given are not sacrosanct, since they vary to some extent depending on the source. However, they do indicate the trend. (ii) Detailed analysis of data is available only up to 2003–04 and in some cases 2000–01. More recently, there are indications that some changes have started happening for the better, but detailed authenticated data are not available.

The available data as of 2003–04 indicate that India had 39.2 mn (million) graduates (22.3% in the science stream), 9.3 mn postgraduates (19.4% in the science stream), and 0.3 mn doctorates (33% in the science stream)¹. The number of graduates as per 1991 census report was 20.5 mn. The gross enrolment in science (graduate +) during 2003–04 was 3.29 mn, representing 34.6% of the total enrolment. The growth rates were: graduate, 21 (1995–96) to 33.1% (2003–04) and postgraduate, 36.5 (1995–96) to 41.4% (2003–04). The annual growth rate between 1995–96 and 2003–04 was from 6.5 to 7.9%. Engineering education showed the highest growth rate, from 8.2% per annum during 1995–2000 to 21.9% during 2000–04. Postgraduates increased from 0.7 mn in 1995 to 1.7 mn in 2004. The numbers enrolled in science increased by 2.7 times, while those in engineering increased by more than ten times. Enrolment for graduates increased by 1.3% between 2000–01 and 2003–04.

This gross picture would sound encouraging but just 1% of total graduates/postgraduates¹ ultimately enrolled

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for Ph D in 2000–01. The poor entry into higher degrees in the sciences is well reflected by the recent data obtained from the UGC (Table 1).

Although there is a phase difference of a few years between the ‘enrolment’ and ‘completed’ figures for a given year, the trend is pretty much clear. Considering the figures in the sciences, although the number of graduates enrolled is 19.6 lakhs, the completed figure is 3.3 lakhs. For postgraduates, the enrolment figure is 2.5 lakhs and the completed figure is 75,000. For Ph Ds, the enrolment figure is 23,000 and the completed figure is around 6000. Assuming that there is no drastic change in enrolment in a span of 3–5 years, it is clear that only a small percentage of graduates opt for postgraduation and even less ultimately opt for Ph D. This is also because the number completing is only 15–25% of the number enrolled at every level. This is not only true in the sciences, but is also a general picture with all subjects included. Thus, the total number of Ph Ds has only increased from ~5000 in 1998–99 to around ~6000 in 2007–08.

Performance indicators – A comparative study with China

Ph Ds in science and engineering

The data given in Table 2 (computed from Prathap²) would indicate that in 2003–04, the number of Ph Ds in the sciences was about the same in India and China (5539 vs 5665). But the number of Ph Ds in engineering was strikingly different (779 vs 6573). The rate of growth in China between 1995 and 2005 was significantly higher than in India, since China started from a lower baseline in science in 1995. Especially, China’s growth in producing Ph Ds in engineering is phenomenally high, justifying its effort to become the manufacturing capital of the world.

Table 1. Enrolment and completion statistics in the science degrees (2007–08)

	Enrolment		Completed	
	Total (mn)	Science (mn)	Total (mn)	Science (mn)
Graduates	9.80	1.96	2.05	0.33
Postgraduates	1.03	0.25	0.54	0.075
Ph Ds	0.07	0.023	0.018	0.0059

Table 2. Number of Ph Ds in science and engineering

Area	India		China	
	1995–96	2003–04	1995	2004
Science	3665	5539	1758	5665
Engineering	335	779	1659	6573
All subjects	9070	13,733	4364	18,806

It is also reported³ that as per the National Bureau of Economic Research (US), China would surpass the US in the number of Science and Engineering Ph Ds by 2010.

Papers published and patents filed^{4–6}

The data presented in Table 3 indicate that while China is surging ahead to account for 6–7% of the total scientific publications of the world^{7,8}, India accounts for less than 2%. The number of scientific papers⁹ from India included in the Science Citation Index (SCI) fell from 14,987 to 12,227 between 1980 and 2000, while China’s grew from 924 to 22,061.

The picture may be changing for the better in India (Figure 1), as seen by the steep rise in the curve¹⁰, indicating the number of research papers in SCI after 2003–04. In addition, analysis by the National Institute of Science & Technology (NISTADS), New Delhi, gives a more encouraging picture than the general tenor of a fall in scientific publications¹¹. The data cover a period of six years, viz. 1985–86, 1993–94 and 2001–02. Based on the analysis of data from *Web of Science* (Thomson-ISI, USA), which covers 5700 journals, unlike the SCI which covers only 3700 journals, it is concluded that India posted an average growth rate of 4.3% in its S&T publications

Table 3. Papers published and patents filed

Period	India	China	USA
1995–2006	211,063	422,993	2,907,592
2007–08	~20,000	~80,000	~250,000
Per cent of country’s papers among top 1% cited	0.33	0.52	1.87
Rank	13	10	1
Patents filed (2007–08)	35,000	2,451,600	~500,000

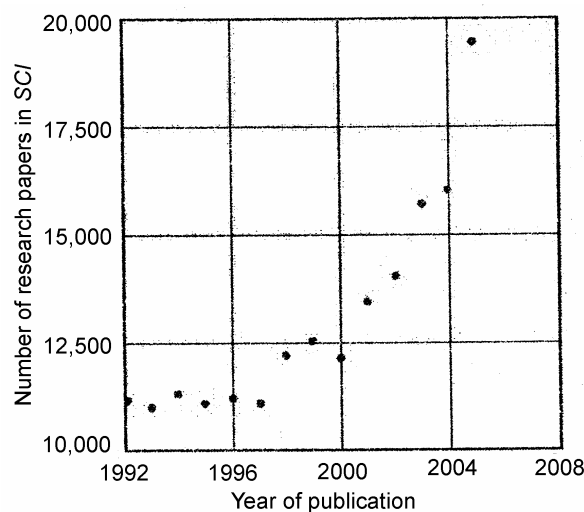


Figure 1. India’s research publications from 1992 to 2005 (Planning Commission, Govt of India¹⁰).

between 1993 and 2003, contrary to the general impression of a stagnation. The impact factor per paper (with all its limitations to judge quality) has increased from 0.748 in 1985–86 to 0.806 in 1994–95, and to 1.229 in 2001–02. But, the fact remains that 70% of the papers is published in low impact or no impact journals. The performance of S&T institutions continues to rise, whereas the university sector has shown a decline. It needs to be pointed out that the absolute numbers vary depending on the databases used, viz. *SCI*, *SCIE* and *SCOPUS*.

India and China face an anomalous situation in terms of publications. Areas such as agriculture, veterinary science and medical practice generate papers of local interest and a substantial number is published in national journals. This is indeed of national relevance. But, the quality of papers published is uneven, since many local journals do not have a proper peer-review system. There is a move to include national journals and those published in different languages in the *SCI*. Since English is the preferred language for science communication, journals published in other languages are at a disadvantage in citation index calculations. However, India which uses English as the predominant medium for science communication is behind, despite the language advantage. There is also concern that scientists clamouring to publish in international journals of repute in modern areas of science, hurt the local journals in traditional areas of science in terms of standing and credibility. There is also a concern that obsession to modern science at the expense of traditional areas of importance can hurt the society, as is evident from the statement 'they can send a satellite to Mars, but not solve most basic problems that threaten million of lives in the developing world'¹².

Strength of HRST and FETRS

The total HRST (human resource in science and technology) was estimated at 40.2 mn, which was 11% of the total work force of the country¹. Only one third of this (14.2 mn) was found to be in core HRST occupation and the rest not utilized in the sector. The FETRS (full time equivalent researchers) data indicate that China has 7–8 times more R&D personnel. The GERD (gross expenditure on R&D) per mn, for China was 12 times more than that for India. China's total investment in R&D was 12–13 times more than that of India. The data are given in Table 4 (refs 1, 13, 14, 18).

Possible reasons for inadequate number of S&T personnel

Attitude to science at the tertiary level

The India Science Report¹ states that in classes 6–8, 30% of the students wanted to become teachers, which decli-

ned to 23% in classes 11 and 12. Popularity of science subjects had taken a dip in the 1990s and early 2000, as can be seen from case studies with students of the Central Board Secondary Examination and Indian School Certificate Examination¹⁵. Based on the number of students who appeared in the 10 + 2 examinations, a priority index was worked out using several enrolment parameters. Essentially, while this showed an increasing trend for accounts and economics, the combined trend for physics, chemistry and biology showed a decreasing trend between 1992 and 2002. Similarly, a case study with Delhi University, where the colleges are better endowed and equipped than those in other states, the drift rate from B Sc and B Sc (Hon) in pure sciences to professional courses such as engineering and medicine was around 50%. This explains why the number of students getting into and completing higher degrees in science is poor, despite an increase in the total number of graduates (Table 1). In the last few years, science courses at the graduate level are attracting greater enrolment, but the intention is to get into the IT sector, rather than venture into higher education in science. With a phenomenal increase in engineering colleges in the states, even candidates with a low ranking in entrance examinations are able to get admission into some engineering college. It is essentially the left-over candidates who get into postgraduate education in science. With the imposition of a ban on the recruitment of regular faculty in colleges and universities in many states till recently, such postgraduates get into positions of ad hoc/guest faculty for a paltry sum.

Science education in colleges

It is again an egg or chicken story. The quality of faculty, especially in colleges has suffered in view of a ban on recruitment of regular faculty till recently, in many states. Poorly paid ad hoc faculty with a Master's degree teaching postgraduate courses is not a formula to ensure quality education. Even private institutions with imposing civil structures do not have well-qualified faculty, with a few exceptions. There is very little research environment in postgraduate colleges, with the result that teaching fails to keep pace with the progress in global science. There is an artificial separation of research in science and teaching, which prevents automatic modulation of syllabuses. According to data available on college resources¹⁶,

Table 4. Research workers/scientists and investments

	India	China	USA
FETRS/mn	~130	~850	~4400
FETRS (total)	115,000	850,000	1,150,000
GERD/mn	20	240	1006
Expenditure/yr (rupees in crores)	~20,000	266,000	–
% GDP	~0.8	1.23	~3.0

the annual budget even for well-known colleges is low, although the tuition fee has remained frozen. The sciences are practical intensive subjects and practical classes suffer due to lack of funds to purchase modern equipment, hire skilled technicians for maintenance, purchase chemicals, books/journals for the library or to provide for on-line subscription, and the vagaries of power supply in the absence of generators. Even the small percentage genuinely interested in science gets disillusioned and drifts into professional courses, with the result that students have very little exposure to experimental science. Undergraduate colleges lack funds to organize modern laboratory exercises, again with a few exceptions. Rural colleges suffer more in this context than urban colleges.

A positive example

In this scenario of falling standards in overall science education and research, a limited success story is seen in the area of life sciences. This is because of the dedicated role of the Department of Biotechnology (DBT) and other funding agencies, Government of India, to bolster this area in the country through improving research. DBT created several new institutions all over the country for research, with infrastructure in terms of providing modern equipment, organized advanced training programmes within the country and abroad for budding researchers and also facilitated industry-academia interaction. More importantly, in collaboration with UGC it started M Sc (Biotech) programmes in six universities in the 1980s, providing admission through an all-India entrance examination. This Master's programme has been multiplied over the years in different areas such as agriculture, medicine and technology. The net result of all these efforts to provide the supply line is a significant enhancement in the quality of research in biology, as evidenced by the number of publications in medium to high impact international journals¹¹. The biotech industry is also fast picking up. The flip side is the hype in the projection of the prospects for biotechnology as next only to the IT sector. There has been a surge among graduates and PG students to opt for subjects such as biotechnology, microbiology, biochemistry, etc. in the last 5–6 years. This has led to all state and private universities starting Bachelor's, Master's and B Tech programmes in biotechnology and self-financing courses without any regulatory mechanism. More often, the poorly trained students are being left without jobs or future prospects. This can seriously affect the morale of students and their parents, who have paid heavily to earn degrees in biotechnology. It is high time that UGC and DBT join hands to introduce norms for maintaining the quality through some accreditation mechanism. DBT has plans to identify and support 'star colleges' to ensure quality education in life sciences. It

also is trying to place as many Master's degree holders as possible in industry. The basic positive initiative of DBT to improve the quality of research and teaching in life sciences has paid dividends, although one needs to be wary of the backlash due to the hype and uncontrolled expansion.

Difference between central, state universities and national institutes

Central universities under the UGC are better funded than state universities. The former also receive substantially higher research grants through sponsored projects from various R&D agencies such as DST, DBT, CSIR, DAE, DRDO, etc. The quality of faculty teaching, and exposure to laboratory courses and projects are of a higher order in central universities than state universities. Many state universities do not follow the UGC norms in terms of scale of pay, career path for faculty or infrastructure requirements and, therefore, the students suffer. To some extent Delhi University colleges and those associated with a few other non-unitary central universities have a higher standard of teaching in science than colleges associated with state universities. Autonomous colleges tend to do better in science education. Self-financing colleges and courses have introduced a distortion in science education. Similarly, private universities resort to advertisement blitz and there has not been a systematic evaluation of the performance of science teaching in these environments to pass judgement. The biggest concern at present is the quality of graduate and postgraduate science education in state universities and associated colleges due to lack of both adequate funds and good faculty, and political interference. National institutes in general are better funded and have a better infrastructure for research than the university sector and therefore, tend to attract better quality scientists at the expense of university requirements. In terms of R&D, these institutes do compete in global science, but have fallen short with some exceptions, as the statistics given earlier would indicate. Many of these institutes have Ph D programmes recognized by specific universities. These Ph Ds in general are of a higher calibre than the ones generated in universities. The participation of these national institutes in terms of teaching postgraduate courses in nearby colleges/universities in general is poor. It also needs to be recognized that Ph Ds generated by the national institutes or even central universities tend to seek greener pastures abroad on a permanent basis (although reversal of this trend might have started), leaving Ph Ds generated by state universities to form the bulk of the pool available for research and teaching in the country. Therefore, improvement in the standard of science teaching and quality of research in state universities and their constituent colleges is a priority.

What is in place and what is on the anvil?

As already stated, the clear signs of slowing down of Indian science have led to several actions being taken by various funding agencies during the 10th Plan and trends of reversal are already being seen. However, data from authenticated studies on the recent picture are not available. It is, however, clear that India has a lot of catching up to do to reach its goal of a knowledge power. Therefore, a quantum increase in funding to education as such and several measures to tone up basic research and teaching in science as well as to attract and retain talent have been taken in the 11th Plan.

To review the strategies in place, a long-term measure implemented by the UGC has helped sustain research and teaching over the years in identified universities. This is through the sanction of assistance at three different levels – Special Assistance Programme (SAP), Department of Special Assistance (DSA), and Centre for Advanced Studies (CAS). So far, UGC has granted 397 SAP/DSA/CAS programmes to universities. The inter-university facilities created at three different centres, IUCAA (Pune), IUAC (Delhi) and UGC–DAE Consortium for Scientific Research (Indore) are models to emulate. A major initiative is the conduct of NET examination in the country to establish a minimum standard to enter the lecturer profession, and this is now widely accepted as a benchmark.

The expansion planned is both horizontal and vertical. UGC¹⁷ has plans for 30 universities with world-class standards and infrastructure in the 11th Plan. Plans are also afoot to set up 370 colleges in backward districts. There would be 16 new central universities in addition to the 20 already in place and 14 world class universities. The aim is to increase the gross enrolment ratio, with the percentage of youth in the age group 18–23 in higher education going up from the current 10 to 15 by 2012. This still falls short of the projection of the Knowledge Commission that India should have 1500 universities to make it a knowledge society! A UGC committee has recommended 735 universities by 2012 to increase enrolment into higher education from 10 to 15%. An empowered committee of the UGC for basic scientific research in Indian universities has made specific recommendations to upgrade science education and research. Some of these are: (i) 1800 JRFs to be granted to each science department under DRS/CAS/DSA/university centres for potential excellence; (ii) Fill in 1000 faculty positions through global advertisement; (iii) UGC networking summer/winter school centres; (iv) Support to non-SAP departments; (v) University–CSIR linkage; (vi) MSc programmes with research component and (vii) Infrastructure strengthening grants to 700 science departments of 97 colleges with potential for excellence.

The Report of the Steering Committee on Science and Technology for the Eleventh Five Year Plan (2007–12),

Government of India, has detailed out the ongoing programmes and the plans for massive improvement in higher education and research in the sciences¹⁰. The details are given below.

DST has taken important initiatives to support R&D in universities and national laboratories. For example, 35 and 6% of the projects sanctioned by SERC in 2005–06 were in universities and colleges respectively. This support has helped improve the quality of research publication, as demonstrated by the impact factor above 2.2 in papers published under this scheme of support. A major initiative of DST to improve R&D infrastructure is through the FIST (Fund for Improvement of S&T in Higher Educational Institutions) and SAIF (Sophisticated Analytical Instrument Facilities). Nearly 240 universities were able to get support for up-gradation of equipment, library and other facilities during 2000–07.

In terms of human resource development, sponsored project and fellowship support provided by various agencies such as DST, DBT, ICMR, CSIR, UGC and DAE, have encouraged candidates to take up Ph D programmes. Similarly, provision of RAs by CSIR and DST and post-doctoral fellowships by DBT have encouraged training of fresh Ph Ds to undertake research projects on their own. These agencies also have fast-track mechanisms to sanction first-time projects by new faculty. More recently, Ramalingaswamy, Ramanujan and DBT–Wellcome Trust Fellowships have been established to attract qualified Indians back home.

It is recognized that India has still a long way to go to be in league with the developed world or China. Therefore, a quantum leap has become necessary in the 11th Plan in terms of investments, augmentation of activities already listed and initiation of new strategies to attract and retain talent. The objectives are ‘Massive revitalization of the university system, expanding post-graduate and Ph D programmes in select institutions and bringing these up to global standards, assured careers to talented young students who opt to remain in science, collaborative projects between colleges/universities and proximate national laboratories for sharing of infrastructure and also faculty support, primarily to develop highest quality human resource and simultaneously improve the standard of the institutions’¹⁰.

DST and other S&T agencies in addition to supporting basic research and other innovative projects of different kinds, have strategies spelt out for up-gradation of research standards as well as nurturing, attracting and retaining scientific talent.

First, there would be augmentation of the existing programmes. For example, KVPY (Kishore Vigyanik Prothasahan Yojana) fellowships, a programme to attract 10+2 students to science, would be expanded from 150 to 450. One innovative programme, INSPIRE (Innovation for Science Pursuit for Inspired Research) is poised for implementation to nurture and retain talent. This has three

components. It has been planned to give Rs 5000 fellowship to 1 mn young learners between 10 and 17 years of age in the next 5 years. The top 1% of the performers would be exposed to mentorship by global icons, including 60–70 Nobel Laureates and 150–200 Indian leaders. There will be assured career opportunity to a 1000 performers up to 5 years after Ph D. National talent scholarships will be given to 10,000 students/year. Ten universities will be selected for S&T up-gradation, with an investment of Rs 200 crores. Twenty universities will receive Rs 75 crores for augmenting new integrated M Sc programmes. Four hundred science and engineering colleges will receive Rs 1 crore each for up-gradation to provide for research by colleges teachers. There will be provision for B Tech (engineering) degree holders to move into the science stream and vice versa. There is also a proposal to have a National Professorship scheme. Provision for sabbatical and international travel for teachers to attend conferences and support scheme to have retired teachers at colleges are also in place. The details of all these initiatives are available¹⁰, subject to the actual allocation to be made by the Government.

The MHRD has plans to start several new institutions of higher learning. To emulate the 100 year-old Indian Institute of Science (IISc) at Bangalore, three IISERs (Indian Institute of Science for Education and Research) have already been started at Pune, Kolkata and Mohali, emphasizing the importance of both education (5-year M Sc integrated programmes) and research. The projected list includes 8 IITs, 7 IIMs, 5 IISERs, 2 SPAs, 10 NITs, assistance to 1000 new polytechnics and 374 degree colleges. The DAE has started a similar institution called NISER (National Institute for Science Education and Research) at Bhubaneswar. The concept of university and promixal national institute interaction and mentoring is emphasized in all these initiatives.

Concluding remarks

Perhaps, lack of priority attention to higher education for a period has resulted in a decreasing trend in several parameters governing quality education and scientific research during the 1990s and early 2000. This has come as a glaring comparison with China, that has made large strides to become a world leader. This has now been recognized and during the 10th Plan some initiatives were taken to correct the situation. The 11th Plan holds promise for a quantum jump in investments and strategies to catch up and put India in a trajectory of logarithmic growth in science education and research. The biggest challenge of all is to find adequate human resource to man and run all the institutions of higher learning that are being announced on a daily basis. It is difficult to hazard a guess, but the requirement of teachers and scientists would run into several thousands to fill up the existing vacancies (if they are released) and the new positions. Al-

location of land and putting up civil structures or giving names such as IIT, IIM and IISER will not guarantee quality higher education and research. Emphasis on teaching alone without hastening the creation of research facilities will fail to attract good quality faculty to the new institutions. On the other hand, sub-optimal and hasty efforts to start new institutions will only lower the prestige of the few brand names we have. The other worry is the state governments trying to outwit one another by announcing new engineering and medical colleges, new universities, up-gradation to IITs and central universities, etc. Education has become a huge business and political interference can only harm the credibility of the new or old institutions. I do not believe that we have enough competent and committed NRIs knocking at our doors to imagine that the human resource problem can be easily tackled. The first thing is to attract students to take up a career in science at different levels and the basic requirement is to make the career attractive and satisfying, with accountability. I believe that fresh Ph Ds with a good record and potential should be offered faculty positions with an inbuilt provision for training abroad for a period not exceeding 2 years within the first 5 years of employment. Special incentives and enabling provisions to attract and retain women in this profession need to be implemented seriously. The initiatives included in the 11th Plan have been already described. This has also formed the basis for the recommendations of the Pay Revision Committee of the UGC (2008) for universities, and one hopes that the Government would implement the package. This would be followed by a similar attractive package for IITs, IISc, etc. However, scientists working in national laboratories such as those of CSIR, DST, DBT, DRDO, ISRO, etc. would be left behind in terms of salary and status. It is time that the Government takes a holistic view of the entire scientific community in the country, irrespective of whether one is working in a university or a national laboratory. While the overall ultimate objectives of the two sectors could be different, both need high-quality science and scientists. I believe that the salary structure and promotional avenues should be similar for the two sectors, with consultancy opportunities being variable. Scientists in the national laboratories should also be involved in teaching through formal programmes, linking the universities with the national laboratories. The age of formal retirement for the entire scientific community should be 65 years. With the kind of numbers we require, I believe we need to have as many senior scientists around as possible, while inducting young and fresh blood into a career of research and teaching. We, of course, need to leapfrog, but we should also worry about the landing terrain. Should we not hasten carefully, if not slowly?

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