MEETING REPORT

Scientific advancements in independent India*

Where are we in terms of scientific advancement, 69 years from independence? This question was the basis for a recent workshop where at stake were questions relating to the tangible outcomes of investments in Science and Technology (S&T) beyond mere publication, as true of India as of other nations around the world, authoritarian regimes to democracies. In such a context, this workshop was aimed at understanding the impact of S&T on Indian society in the years after independence from a historical perspective, with a view to enabling relevant stakeholders to make appropriate recommendations for future policies. A group of eminent scientists, social scientists, economists, historians and science journalists came together for a serious exchange of views. The major areas discussed were education, space and aeronautics, healthcare, information technology (IT), agriculture and biological conservation. The workshop was divided into 7 sessions, including 12 talks and 6 panel discussions. The 50 participants belonged to eight premier research institutes and universities across India along with one representative from King's College in London, working on the history of science and technology in modern India. The workshop deliberated upon the impact of S&T compared to intended goals at the time when particular projects were conceived vis-à-vis policies on various S&T related sectors. The motivations for framing such policies themselves were also analysed. A major theme explored was whether the policies adopted were mainly implemented to overcome the crises of the day, or whether they were based on a more far-reaching vision for the country. The workshop not only discussed successes of the S&T enterprise, but also considered its failures, which in major part was due either to lack of state support or of relevant expertise in the national scientific community.

The powerful plenary account, 'Science education in the making of modern India' was not entirely enthusiastic. There was, it argued, a major disconnect between research institutes where basic science was conducted with next to no pedagogical remit (with some notable exceptions), and colleges and universities (approximately 40,000 and 700 respectively) where research was pursued in the main indifferently at best, if at all, and where the quality of teachers and students was variable. From this unhappy situation, the country was expected to produce leading scientists and top-notch science, despite the fact that the typical scientist in a university is no longer involved in active research, while active researchers in institutes are rarely involved in any core teaching. This was and remains completely at odds with the spirit of Article 51A of the Constitution of India, which exhorts its citizens to 'develop a scientific temper, humanism and the spirit of inquiry and reform'. The hyperbole inherent in the latest Science Policy (2013), claiming that India will take its place among the top five nations in terms of housing the most exemplary scientific institutions notwithstanding, it was instead to 1958 (with the first Science Policy) that it was recommended that we might profitably turn, given the measured tones of that document, where science met a variety of needs – basic, applied and educational. The key point in that statement was that scientists themselves should hold an honoured position in the enunciation of scientific policy, in studied contrast to the present day where scientists are seldom, if ever, consulted and where they in turn shy away from intervention in the framing of such policy. Simply put, in today's India, 'science and science education is a house divided'.

It has generally been observed that in a developing nation such as ours, the link between basic science and technology development is not strong enough to translate the ideas from one side to the other. If the distribution between science and technology is skewed, it is neither good for science nor for technology. Therefore, the Government needs to worry about the distribution of resources and people over the whole spectrum that can involve education and research policy integrated with activities like technology development or encouragement of start-ups or similar endeavours. In this pursuit, the study of the history of science plays a crucial role. The history of science can analyse and explain the relationships between science and policy, with the purpose of advancing knowledge/science enabling critical questioning and enhancing learning capacities. The resource allocation idea described above can be verified by studying historically the development of various sectors.

A cogent presentation on the early years of S&T in India drew attention to the fact that much of what we take for granted as post-independence developments were obliged for their genesis to seminal events that occurred in colonial India during the 1930s and 1940s. These included the development of the nation's experimental nuclear programme (which, it was emphasized, was as much a part of a global phenomenon as anywhere else and should not be patronizingly dismissed as 'derivative', given that key Indians, working abroad, helped to forge it at home on their return) and of its aeronautical capabilities by expatriate Germans after the war, even as Hindustan Aeronautics Limited came into being as a consequence of the South East Command arranging to have its planes serviced in Bengaluru (then Bangalore) in the same period. The establishment of now such a venerable institution as the Council of Scientific and Industrial Research had its bureaucratic beginnings emerge also from a militaristic precursor – the Second World War. Following that global cataclysm, India's commitment to non-alignment saw results both in steel plants and the Indian Institutes of Technology, where individual entities in each section were created in collaboration with nations on either side of the Cold War divide.

One area of seeming hope today is the Indian Space Research Organisation (ISRO), which in recent times has received wide public attention due to several

*A report on the workshop titled 'Scientific Achievements for Independent India' held at the Indian Institute of Science Education and Research, Pune on 12 and 13 August 2016.

successful space missions. While space launches attract publicity, what is generally not highlighted is that the organizations under the ISRO umbrella have a full spectrum of people involved, including the basic sciences (Physical Research Laboratory, Ahmedabad), technology development (Space Applications Centre, Ahmedabad), educational institutes (Indian Institute of Space and Technology, Thiruvananthapuram) and enterprise through a commercial arm (Antrix, Bengaluru) consisting of human resources distributed as nominally described in Figure 1 (which in this context can be viewed in a more positive frame). A large fraction of the work force in ISRO consists of engineers engaged in innovation and technology development, and a smaller proportion of people is involved in basic science and commercialization as shown at the two opposite ends of the spectrum in Figure 1. This skill-based distribution across the spectrum was originally proposed by Vikram Sarabai, father of the Indian space programne, and is still maintained at all ISRO facilities. As a result, everyone involved feel ownership and are respected by each other. This model should ideally be sustained, even while the organization is growing.

The cases of both pharmaceuticals and the IT industry make for an interesting topic of study in comparison with ISRO.

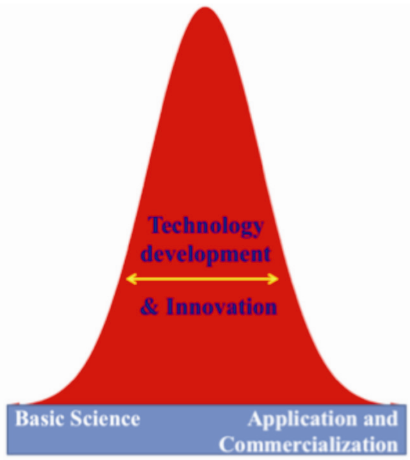

Figure 1. Statistical distribution of the science and technology workforce in scientifically advanced societies. (It is clear from the figure that only a small proportion of the workforce is involved in basic science or its application, development and commercialization, while the majority forges the link between the two ends of the spectrum.)

While each has benefited from Governmental polices in the 1970s and 1980s and gained stature worldwide, much still remains to be done at the discovery and new product/innovation end. A large work force in both industries is engaged in generic drug manufacturing and in providing IT services respectively. With time these areas become saturated either because the field gets obsolete or there is less scope for growth, and as a consequence growth in that sector gets curtailed. The cessation of growth will soon lead to a crisis situation in each of these areas. Before such a situation comes into being, it is imperative to set right policies for these sectors and to effect such education as feeds into related and allied technologies.

Agriculture is another technology-based sector that has provided livelihood to more than 50% of all Indians (although the GDP from this quarter has reduced from about 75% in the 1960s to about 12–13% at present). The early policies of the 1960s were in response to crisis situations and they helped to usher in the Green Revolution that not only made us self-sufficient in food, but also boosted the confidence of the entire nation. With the growth of other sectors and little corresponding change in policies, agriculture has become an unattractive profession for the younger generation. The survival of this sector largely depends on new technological inputs and major policy changes for the sustainable growth of agriculture and allied industries. Among all sectors discussed climate change affects agriculture more severely and to tackle this issue, greater technological interventions, lifestyle changes and awareness are required. In this, science in the universities coupled with their educational programmes can play a significant role based upon the scale of exposure that students receive.

On the other side of the agricultural debate is biological conservation, where forest land is typically denuded to be given over for the cultivation of crops. Ironically, after forestry was removed from the purview of the Public Works Department in the late 19th century, it was placed alongside an area with which it had found itself traditionally in conflict – agriculture (plus revenue and commerce). In the 1960s, however, forests were seen as allied with issues of maintenance of charismatic megafauna, in particular, the tiger. In 1972, the Wildlife Protection Act was passed and the same year, the tiger replaced the lion as the national animal, keeping in mind, as Karan Singh who helped spearhead Project Tiger said, that the tiger was found in many states of the country and was a symbol therefore of the unity and diversity of India, while the lion was found only in one state (Gujarat). Gujarat in turn promptly named the lion its state animal and the result was the relocation of the buffalo-herding Maldharis out of the now designated Gir National Park, resulting in tremendous privation for that unfortunate community, not least the loss of grazing land for their animals (a situation replicated in several communities around the country) and even more cripplingly, traditional rights of usufruct. Was the notification of once princely hunting reserves as Protected Areas the way forward? The conservation lobby is divided – some completely concur, others demur, suggesting that spaces for nature cannot be vouchsafed at the expense of spaces for people, particularly those thus displaced. Ultimately, is conservation a luxury for the educated elite, while the majority stay excluded from and uninvited to the larger conversation? Hopefully, with the promulgation of such far-sighted legislations as the Forest Rights Act (2006), the fiat of the few will cease to hold such sway.

The time has come to recognize that scientific theory and research cannot be considered an elite knowledge-gathering pursuit, but should also contribute substantially to addressing ground-level problems. At present India contains sufficient professional expertise to handle the technical challenges at all levels. However, education even in premier research institutes is not geared to prepare students to generate solutions for reasons discussed earlier. Within a population of 100 bright students at any reputed research institute, it is unreasonable to expect that all of them should opt for the basic sciences. However, the current teaching structure is often designed around examinations and the viva voce, which frequently does not leave time for students to adopt a problem-solving approach to address lingering social challenges and thereby occupy their legitimate places in the spectrum discussed above.

If we wish to emulate the success of ISRO in other S&T sectors, including science education, resource distribution becomes crucial. Furthermore, we are now at the point where both the state of the nation internally and its status globally are so demanding of attention that we must take the longer-term view, rather than merely responding to crises or immediate requirements. If we cannot cater to the needs and aspirations of our significantly large young population, the result will be mayhem. In harnessing the population-based advantage for S&T, the creation of wealth will ensue, which can only lead to overall societal benefits in other sectors as well.

A heartening story emerges from the world of IT, where in its much lauded 'revolution', the drivers have really been individuals running small team science. One of the key elements inherent in the system is capacity building. Taking a cue from this account, it might be worthwhile considering what small group initiatives can bring to collegiate and university settings, particularly since they, along with research institutes, generate the trained human resources necessary for the spectrum covered by all science sectors. If India has succeeded in such big mission-mode projects as agriculture, vaccination and space, it is because the nation had already produced quality human resources in sufficient numbers to populate those sectors. As the S&T enterprise expands, it will be imperative that we nurture its support system alongside, i.e. higher education centres that provide trained human resources. However, as pointed out earlier, research and teaching have largely been divorced in the 20th century higher education in India. The result is that scientists who teach do not conduct active research in universities, while the reverse obtains in institutes. As a consequence, an appropriate dually trained workforce fails to be generated, resulting in a nation that risks losing relevance. To counter such a possible catastrophe, our educational system needs to account for diversity where the potential of each researcher or student must be recognized for different capabilities, which results in an inclination to address different kinds of problems. Such recognition allows for a plenitude of avenues to be made available based on the kind of knowledge brought to the table coupled with the exigencies of the S&T set of requirements at hand. This will allow for a true ecosystem of S&T-based activities.

Understanding the journey of various S&T-related sectors in the country after independence through such workshops or related forums is an important starting point in effecting the formulation of future policies. If anything, this effort must be viewed as part of a continuing critical dialogue between science and society. Besides specific issues at stake, we have sought to generate ideas and debates that will enable both scientific creativity and all-round inclusive development of the potential of our people and the country in a sustainable manner. Above all, this workshop has undergirded the fact that it is time to reinvoke the spirit of the 1958 Science Policy document so as to reclaim the place of influence for the trained scientist and technologist in helping to shape the future of the nation through collaboratively devising the architecture of her scientific policies.

Sarita Ahlawat, Birac_BIG Scheme, Unit-1, Technology Business Incubation Unit, Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110 016, India; **Mahesh Rangarajan,** History and Environmental Studies Department, Ashoka University, P.O. Rai, Sonepat 131 029, India; **L. S. Shashidhara,** Department of Biology, Indian Institute of Science Education and Research, Dr Homi Bhabha Road, Pashan, Pune 411 008, India; **John Mathew*,** Department of Humanities and Social Sciences, Indian Institute of Science Education and Research, Dr Homi Bhabha Road, Pashan, Pune 411 008, India.
*e-mail: john.mathew@iiserpune.ac.in

MEETING REPORT

Electron microscopy*

An international conference on electron microscopy (EMSI-2016) was held recently, coinciding with the year-long centennial celebration of the Banaras Hindu University (BHU), founded by Pt. Madan Mohan Malaviya in 1916. It is well known that BHU has contributed immensely to electron microscopy research since 1963 and has produced many renowned electron microscopists since then.

This conference was aimed at bringing together a large number of distinguished researchers, microscopists and technical experts from across the globe to discuss the latest advancements on the characterization of materials at the atomic level. For the benefit of the participants and young researchers, three pre-conference workshops were organized (30 May–1 June 2016) on: (i) Electron microscopy in materials science, (ii) Electron microscopy in biological sciences and (iii) Electron probe micro analyzer (EPMA). Nearly 100 participants, mostly young researchers and doctoral students from all over the country attended the workshops. Subsequent to the workshops, more than 300 participants from various countries attended the conference on electron microscopy. There were 14 plenary lectures by experts drawn from India and abroad, and 121 oral presentations of which 54 were invited lectures and the others contributory. Poster presentation sessions consisting of 95 papers and metallography contests with more than 30 entries were also conducted. Twenty technical sessions were planned over three days covering subjects such as nanomaterials, steel, nonferrous and complex metallic alloys as well as various techniques such as SEM-FIB, EBSD, electron diffraction, HREM, atom probe tomography, etc. Some sessions were also devoted to biological as well as earth and planetary

*A report on the International Conference on Electron Microscopy and the XXXVII Annual Meeting of the Electron Microscope Society of India (EMSI), organized by the Department of Metallurgical Engineering, Indian Institute of Technology (BHU), Varanasi in association with EMSI during 2–4 June 2016 at Varanasi.