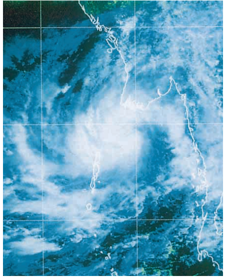

CHAPTER IV

Science Education

Historical Background

With a long and chequered history of education and training in pure and applied sciences dating back to over 2,600 years, India has had flourishing tradition of scientific research and technological development. Taxila (6th century BC) one of the earliest universities in the world, attracted students from across the continents. Major fields of study at Taxila included mathematics, astronomy, medicine, surgery and metallurgy. Unfortunately, most of the knowledge was lost during the medieval period. The glorious tradition of original thinking, adventure of ideas and creative innovations was completely snapped.

Science and Science Education During the British Rule

The development of modern science in India is not an organic extension of the earlier tradition. It is an implant by the British in a language that was alien to its people. As with other implants, it needed nourishment and nurturing to be absorbed in the society. Science education was lacking and science was looked upon as an appendage thrust by the British for their own benefit.

Until a few decades towards the end of the British rule, the role of science education, scientific and technological research in economic growth and social transformation was rather limited. Only such developments were introduced that did not lead to a conflict with the interests of the colonial power. The only aim of education including that of science education was to turn out men competent to serve the civilian administration. Consequently, science education and research was uneven and patchy with no facilities. Even those few individuals educated in science lacked opportunities for either gainful employment or for scientific research. They could only procure clerical or teaching jobs.

It was only in 1857 that the universities of Bombay, Calcutta and Madras, modelled after the London University, were established. As a concession to the Indian aspirations the foundations for basic sciences were expanded and academic science in the universities received a fillip. It must be stressed that even under such adverse conditions, globally competitive scientific research was carried out by a few scientists like, C.V. Raman, M.N. Saha, S.N. Bose, D.N. Wadia, P.C. Mahalanobis, S. R. Kashyap, Birbal Sahni, S.Ramanujan, S. Chandrashekhar. Many of these were trained in India and carried out their research in Indian universities.

The outbreak of the World War I brought about a radical change in science education and in the pattern of scientific research and technological developments. The colonial government being cut-off from Britain was forced to actively mobilize local resources of scientific and technical personnel to meet wartime needs.

Post-Independence Period: Nehru's Vision

Within a few decades of the end of World War I, major colonial empires had disintegrated and India became independent in 1947. It is indeed very fortunate that Jawaharlal Nehru was India's first Prime Minister. Having witnessed first hand the remarkable developments brought out through the pursuit of science in Europe and particularly in the then Soviet Union, he more than anyone else, realized the crucial importance of science for economic growth and social transformation. Addressing the then National Institute of Sciences (now INSA), Nehru stated, *Who indeed can afford to ignore science today? At every turn, we have to seek it's aid and the whole fabric of the world is of it's making.* He strongly emphasized the inherent obligation of a great country like India with its tradition of original thinking to participate fully in the march of science. It was equally fortunate that in laying the firm foundation of science and science education in the country, Nehru's vision was shared by the then leaders in science who helped Nehru to realize his vision. Raman, one of India's most eminent scientists said, *There is only one solution for India's economic problems and that is science, more science and still more science.* Homi Bhabha, the father of India's atomic energy programme, while addressing the General Assembly of the International Council of Scientific Unions, just before his death, emphasized, *What developed countries have and what developing countries lack is modern science and an economy based on modern technology. The problem of developing countries is therefore the problem of establishing modern science and transforming their stagnant and traditional economy to the one based on modern science and technology.* Bhabha went on to add, *An important question we must consider is whether it is possible to transform the traditional economy to the one based on modern technology developed elsewhere without at the same time establishing modern science in the country as a live and vital force? If the answer to this question is in the negative and I believe our experience shows it to be so, then the problem of establishing science as a live and vital force is an inseparable part of transforming an industrially underdeveloped country to a developed country*. In the context of establishing modern science and technology as a live and vital force, the importance of science education cannot be over-emphasized. Indeed, science education plays a crucial and pivotal role in the alchemy of scientific research and technological innovations.

> While delivering the convocation address of Allahabad University in 1946, Nehru said, *It is science alone that can solve the problems of hunger and poverty, of insanitation and malnutrition, of illiteracy and obscurantism of superstition and deadening customs, of rigid traditions and blind beliefs, of vast resources going to waste of a rich country inhabited by starving millions***.**

Policy Frame

The vision of Nehru of India becoming a beacon spreading to the world not only the message of Buddha and Gandhi of peace and universal brotherhood but also that of science and technology, was translated into working plans through a policy frame that has evolved over the years. The very constitution of the Republic of India (seventh schedule) squarely puts the responsibility for coordination and the determination of standards in the institutions of higher learning and research on the central government, its responsibility also includes central universities, Indian Institute of Science, Institutes of Technology and institutes of national importance declared by the parliament. The constitutional amendment of 1976 places education including science and technology education in the concurrent list which implies the joint responsibility of the central and the state governments. The Government of India has evolved a machinery to discharge these obligations by designating Ministry of Human Resource Development to function as an administrative ministry and by establishing the University Grants Commission and the All India Council for Technical Education, by acts of parliament to superintend the functioning of higher education in science and technology respectively.

Over the years, the Indian parliament has adopted major policy statements relating to higher education and S&T development. These developments have been largely guided by the Scientific Policy Resolution of 1958, one of the most comprehensive science policy documents ever approved by any legislative body in the world.

The parliament approved in 1968, the Technology Policy Resolution, which states that research and development together with S&T education and training of a high order will be provided a pride of place. Basic research and building of the centres of excellence will be encouraged. The quality and efficiency of S&T generation and the related delivery system will be continuously monitored and upgraded. The policy statement calls for strengthening linkages between educational institutions, R&D establishments, and industry and government machinery.

The central government has periodically constituted National Commissions on Education to assess the system of education and for recommending ways and means to diversify, improve and update the system, consistent with the changing environment. Some of the commission's reports were translated into National Policies on Education. Thus the National Commission on Education of 1964 chaired by D.S. Kothari resulted in the preparation of the National Policy of Education in 1968. In 1986, the national Policy was suitably modified, amended and updated. This was further modified in 1992 in the light of Ramamurthy Committee's report covering a whole range of operational, financial and technical issues. The statements emphasize education to be a unique investment for the present and the future, with emphasis on equal access on requisite merit, mobility of students and faculty and networking of educational institutions, R&D establishments, greater autonomy and accountability, relevance of curricula, excellence in research, and mobilization of resources. Thus the statement first made by the Kothari Commission that *the destiny of this country is shaped in the classrooms and laboratories of schools, colleges and universities* is re-echoed.

India has committed whole heartedly to science and has provided the necessary policy support for S&T humanpower development. There is also a systematic planning process in place. The policies and plans have helped India develop a vast infrastructure for higher S&T education, and have provided the second largest manpower in the world, with the best in the system comparable to the best anywhere in the world. However, inadequate understanding of the spirit of the recommendations has led to over-centralisation of authority, bureaucratization by controlling agencies and over-dependence on government support and intervention. The system has become too large and monolithic to ensure quality and accountability.

Growth of the System of Science Education

Recognizing the crucial role played by S&T in the process of economic growth and social transformation, major emphasis was laid on higher science education during early years of Independence. Thanks to the political leadership, conducive policy support and substantial investment, India today possesses one of the oldest, the largest and the most diverse infrastructure. For S&T education and training several institutions comprising the Indian Institute of Technology (IIT's), Indian Institute of Science (IISc), about a dozen institutes of national importance, two hundred and odd universities, and over 8,000 colleges, exist. This infrastructure has already made a substantial impact on the country's scientific, industrial and economic development. There has been impressive development since Independence in various fields such as agriculture, industry, atomic energy, space programmes, manufacturing, and health care.

More than the creditable performance of the S&T personnel in India, the performance of Indian Diaspora cultured in our colleges and universities has been highly impressive. S&T personnel from India are highly sought after and respected in the countries of their adoption. Some of the academic research institutions such as IISc, Bangalore; TIFR, Mumbai; IITs and a few universities such as Delhi, Jawaharlal Nehru University, Poona, Banaras Hindu University, Varanasi, Central University, Hyderabad; and Jadavpur., have developed global reputation and attract increasingly large number of students from South East Asia, Middle East and Africa. The best products of the Indian system are comparable to the best anywhere in the world, although of course the average product is of a poorer quality. Indeed, Indian S&T personnel have assumed leadership role in areas such as statistics, chemical engineering, biochemistry, information technology, biotechnology, advanced materials and are prominently visible in a number of advanced countries.

Everything is not, however, fine and rosy about India's science education system. Despite the fact that India today has the second largest education system, it has still to meet the basic needs and aspirations of its billion people. The level of illiteracy still hovers around 35%. The access to science education is on the average around 30%. There is much to be desired in relation to the quality and relevance of higher science education.

Fortunately, India has recognized too well that only by competing successfully in the globally interdependent economy through its S&T humanpower that the living standards can be raised and the hopes of its people met. It has realized that it is through its reformed, updated and restructured higher science education and training system that the country can advance economically. After an almost explosive growth in the S&T system, at the beginning of the new millennium, India is on the threshold of restructuring and updating its science education system so that the tremendous promise and creative abilities of its talented humanpower could enable the country to redeem its tryst with destiny.

During the last fifty years, every aspect related to science education, whether it be student enrolment, number of educational institutions, and the number of teachers have recorded ten-fold growth. As science education is a continuum, it is necessary to consider its growth and its consequences right from the school level.

Science is taught at lower secondary level as an integrated whole than as a compartmentalized discipline. Discipline-oriented teaching and learning commence at 11th and 12th standards corresponding to the age group 16-18 years. The educational pyramid for a typical year (1993-1994) is shown below.

Educational Pyramid 1993- 94

Level	Number of students		Age Group
Research	55,012		26
Post graduate	237,812		23
Diploma	65,087	1,470,213 1st Year B.Sc.	19
Class XII	3,484,432		18
Class X	6,049,964		16
Class VI	12,827,922		12
Class I	27,353,401		6

Number of students

Student enrolment at every level has been increasing at around 7-10 per cent each year.
These figures may give some idea about the numbers involved in the system at the beginning of the 21st century.

Although, the actual numbers are large, the gross enrolment ratio namely the total enrolment at a given level divided by the population of the concerned age group is considerably low as compared to the corresponding figures for a developed country such as USA as shown in the following table:

Gross Enrolment Ratios %

	Primary		Secondary		Tertiary				Tertiary 1995	
	1965	1995	1965	1995	1965	1975	1985	1995	Male	Female
India	74	100	27	49	5	9	9	7	8	5
U.S.A	100	102	90	97	40	57	58	81	75	92

Looking at the educational pyramid, one finds that within the age group 5-18, corresponding to classes I-XII, nearly 50% of the population remains out of schools. In the age group 17-18 years, the access to education is barely 20-30%. Besides lower access there are gender and regional disparities. Further, due to rapid growth in education starting from extremely low access at the time of Independence, student population at every level constitutes a highly mixed lot such as first generation students mixing with students having several generations of educational background. In addition students are drawn from extremely widely varying social, economic, and cultural backgrounds. These are of course problems of growth itself. One can only imagine the numbers involved, the size of the infrastructure necessary and the resources required to cope with the numbers if the system continues to grow to achieve gross enrolment ratios comparable to those in the U.S.A. This problem underscores the urgent need to restructure educational system to make it more flexible, more accessible as also to use mass communication technologies for imparting education.

In much the same way, science education at tertiary level (college level) has been expanding almost exponentially. Indeed since Independence, the enrolment in the science stream increased from 127,200 in 1950-51 to the present level of over one million. The following table shows the year-wise enrolment and the graduate degree awarded in natural sciences.

Enrolment to Science Courses and First Degree Awarded in Natural Sciences

YEAR	Enrolment in Science Stream		Degree Awarded	
1982-83	623,545	(19.9) *	112,075	(17.97) **
1983-84	653,092	(19.7)	115,085	(17.62)
1985-86	703,467	(17.9)	124,328	(17.60)
1989-90	802,525	(19.7)	134,366	(16.74)
1991-92	902,221	(19.7)	140,222	(15.57)
1998-99	1,105,621	(19.7)	170,225	(16.20)

* Percentage of total enrolment; ** Percentage of passing at B.Sc. level.

A critical analysis of these data is very revealing. In the first instance, one is alarmed by the high level of failures and dropouts. One sees that on the average, the number of students who successfully complete their degree is barely 14-18%. This implies that nearly 82-85% students either drop out or fail to pass. Indeed large dropouts and failures are unique and distinctive features of the Indian education system. This constitutes a tremendous loss of public resources. Even if education is considered as an industry, there is a compelling reason for us to critically examine the causes of massive dropouts and failures and evolve remedial measures.

A look at the table also shows that besides low access to education at this level, the actual numbers enrolled into the system has been increasing. It may however be well to appreciate that the percentage of students opting for science after their secondary examination dropped from 32% in the early 1950's to barely 19.7% in recent years. It is not merely the decrease in the percentage that is worrying but the fact that 32% in the early 1950's were from the topmost rung, in contrast to the present day 19.7% from lower middle level. Both these facts indicate that young students, particularly the brighter ones amongst them, are drifting away from science. This is a matter of grave concern. This trend is also indicated by the choice exercised by the National Talent Search Awardees. Out of 750 awardees, hardly 100 opt for science and only 15-20 go up to the M.Sc. level. These figures indicate that students do not opt for science as a first choice but as a last resort, implying an influx of a large number of unmotivated and uninterested students in higher science education.

Ideally, one would have liked a situation where a large number of talented students are motivated to seek a career in science and one then selects a smaller number namely those who demonstrate a creative bent of mind so essential for career in science. To makes matters worse, nearly 88% of the students who opt for science after higher secondary level are taught in affiliated colleges which are rather ill-equipped, over-crowded and poorly staffed. In these colleges, laboratory and library facilities are woefully inadequate. In such an atmosphere, it is impossible for students to experience excitement of doing science and get motivated to undertake science as a career. As at other levels, the access to education at the degree level is also very low in comparison to the access available in advanced countries.

Enrolment Data at the Tertiary Level

	Number of Tertiary Students (Millions)					Number of Tertiary Students Per 100,000 Population			
	1975	1980	1985	1990	1995	1980	1985	1990	1995
INDIA	3.00	3.50	4.40	4.95	5.70	5.15	5.62	—	6.13
U.S.A.	11.10	12.10	12.20	13.70	14.20	5,311	5,068	5,591	5,339

The above table shows that not only the gross enrolment ratios are low in India but also even the actual numbers are lower at the tertiary level as compared to those in the U.S.A.

In tune with the increase in the enrolment at the college and the university level, the number of institutions imparting science education at the degree and the post graduate level has also been increasing over the years.

Growth in Educational Institutions

YEAR	Universities	Deemed Universities	Colleges	Enrolment (Million)
1976	105	9	4,317	2.40
1980	116	12	4,722	2.75
1985	136	17	5,816	3.10
1990	150	29	7,346	4.92
1995	168	36	8,613	6.40

On an average a university seems to cater to roughly 40-50 colleges and 20,000–30,000 students. However, there are a number of universities which supervise 200–300 colleges and have enrolment in the range of 200,000 – 300,000 students.

The following table gives the doctoral degrees awarded by the Indian universities between 1982-94.

The resources for science and technical education are provided entirely by the state and central governments. This total dependence on government support and intervention has skewed the system and has introduced a number of unhealthy trends. A critical analyses of the above and related data have brought out major issues that need to be addressed if the higher education system is to turn out highly qualified, skilled and motivated youth with whose help the country is to make important economic strides.

Number of Doctoral Degrees Awarded

	82-83	84-85	86-87	88-89	90-91	91-92	93 -94
Science	2,893	2,922	2,814	3,044	2,950	3,386	3,504
Engineering	511	509	603	586	620	323	348

This table is indeed very revealing. It shows that although student enrolment and number of universities have increased, the number of research degrees awarded in natural sciences has almost stagnated, whereas in engineering and technology, the numbers have actually declined.

Finally we may look very briefly at the S&T humanpower data. It was around 4.8 million in 1991. The number of S&T personnel has been increasing at the rate of 6% per year and today it stands around 7 million.

It may be useful to look at the resources available to operate such a large system. In the National Policy on Education of 1968, 6% of the GDP was recommended to be spent on education, but this level of investment has continued to be a mirage. In fact, allocation to education as a percentage of GDP has declined slightly in recent years to stand at 3.5%. The share for higher education in general and science education in particular has declined to 1.0% and 0.2%, respectively. This figure (0.2%) appears far too small when compared to the corresponding figures in advanced countries, namely U.S.A. (1.6%), U.K. (1.4%) and Japan (1.04%). It is a matter of serious concern that investment on each student has nose-dived from Rs. 850/- per year in the 1960's to Rs. 350/- per year (at standard prices in 1990). The allocation for equipment and library in most of the colleges is measly.

Major Areas of Concern

India has realized that in the emerging global scenario — wherein intellectual property will be highly valued and rights will be fiercely exploited and zealously guarded — the only way to improve the nation's competitiveness is through better and more productive science and technical education and flourishing scientific research and technological development. It is clearly understood that the world is passing through a transition from international relations being shaped by military might and political considerations to the one in which they will be increasingly determined by scientific competence and technological capabilities. It has more than understood that the arms race of yesteryears has yielded place to technological Olympiads and that military aggression has been replaced by economic exploitation. It is recognised today that, as never before, the competitive advantage of a nation will be increasingly determined by the quality and the number of its S&T humanpower. The experience of the last 50 years has also underlined that the intellectual raw material available to it in the form of young boys and girls is inherently talented, analytical and motivated and comparable if not better than that available elsewhere in the world. What needs to be done now is to put in place a system of highly productive, exciting and stimulating science education system — flexible and accountable, diverse and yet focused, well funded and properly managed so that these young boys and girls flourish and deliver the goods.

A critical analysis of the data presented earlier has thrown a number of areas of concern that need to be addressed squarely and urgently so that the appropriate system which not only responds to the changing global environment but also provides a future direction is evolved. It appears that India has arrived at the most opportune time to restructure its vast educational system, having passed through a phase of massive expansion.

The major issues that need to be faced are:

- over-centralization, lack of autonomy and flexibility and lack of accountability,
- access to education, removal of gender and regional disparities,
- high rate of dropouts and failures,
- shying away from science of particularly brighter young boys and girls,
- poor quality of production and lack of relevance,

The answers to the above are to be sought by:

- providing equity and promoting excellence, and
- integration of science and technology education and integration of education and research.

> ONE THING IS CERTAIN; YESTERDAY'S EDUCATIONAL SYSTEM WILL NOT MEET TODAY'S AND EVEN LESS TO THE NEEDS OF TOMORROW.
>
> D.S. KOTHARI

Some Initiatives

Educationists in India have identified the areas of concern mentioned above and have responded to them by certain moves. This section describes very briefly the steps taken.

Use of IT in Education: The role of Information Technology (IT) as an instrument for progress and development has been acknowledged widely.

The use of IT tools in teaching will make the learning process considerably simple and affordable. For a large and developing country like India, technology such as Distance Learning needs to be used in a major way to address the problem of limited educational material and resources. A number of projects have been sponsored in collaboration with leading institutions like IITs, IISc, Indira Gandhi National Open University (IGNOU), Nation Council for Science and Technology (NCST), and Birla Institute of Technology and Science (BITS), Pilani, with its long-term objective being promoting both IT based general education and IT based education itself. IGNOU has several IT enabled courses and is further promoting this culture. National Council of Educational Research and Training (NCERT) has set up a National Centre for Computer-based Education to promote training and development of teachers and teacher-educators. The centre will eventually sustain development of school teachers with a culture of resistance to change and provide schools with IT-based inexpensive learning materials in support of the curriculum.

Education Through People's Science Movement: One of the significant leads taken a few decades ago concerns people's science movement (PSM) and education through it. The role of PSM is not only restricted to communicating and simplifying science but also to question every aspect of science-related activities, in particular S&T issues involved and intervening wherever necessary with people's participation.

An outcome of the PSM was the development of the Hoshangabad Science Teaching Programme. Students' active participation in the process of education was a unique feature of this endeavour. Although it marked a significant deviation from the conventional system and proved effective, it has not yet been absorbed into the formal system. PSM has grown and spread all over the country and has led to the upsurge known as *Bharat Gyan Vigyan Jatha* and has helped considerably to create the necessary social ethos for absorption of science and scientific temper in the society.

Exploratory - An Experiment in Learning by Doing Science: A unique institution called Exploratory has been developed at Pune by a few dedicated educators. Exploratory is neither a school or college laboratory nor a museum but is a place where school and college children can explore and experiment, invent and innovate and design and fabricate. There are no teachers in the exploratory but highly experienced guides who explore along with the students the basic concepts in science through carefully designed activities. The purpose is to enable children to learn science by participating in the process of science. The exploratory promotes keen and careful observation, excites curiosity, encourages children to ask questions, question the answers and enables them to generalize and discover.

Although the formal system of science education has not yet adopted the exploratory way of learning science, exploratories are being set up all over the country.

> WE MUST OVERHAUL THE SYSTEM OF SCIENCE EDUCATION IN THE COUNTRY TO BASE IT ON KNOWLEDGE AND CREATIVITY AND NOT ON MEMORIZING AND EXAMINATIONS
>
> ATAL BEHARI VAJPAYEE

Navodaya Vidyalayas: Navodaya Vidyalayas were conceived in 1986 by Rajiv Gandhi, former Prime Minister of India. The scheme aims at setting up well equipped well staffed schools in rural areas, almost one in every district to provide better quality science education to the talented children. These Navodaya Vidyalayas also serve as a resource centre and a pacesetter for the other schools in the region to follow. These Vidyalayas, 425 in number as of today, also aim at promoting excellence and removing disparities.

Proposal for Restructuring Undergraduate Science Education: National Planning Commission appointed a Committee to suggest restructuring of undergraduate science education. The Committee has recommended a three-tier approach to revitalise science education at the undergraduate level.

Although the suggestions have been hailed by the entire scientific community, these have not yet become a part of the formal system.

UGC's Efforts in Promoting Excellence: In recent years the UGC has launched a large number of programmes aimed at promoting excellence. These include:

- autonomous colleges
- faculty improvement programmes
- academic staff colleges.
- centres for advanced studies
- curriculum development councils
- career development programmes
- support for strengthening infrastructure in S&T and removal of obsolescence in the universities
- identification of universities with a potential and supporting them to become comparable with the best anywhere.

Inter-University Centres: One of the most innovative steps taken by the UGC for promoting excellence was the setting up of Inter-University

Centres equipped with most modern experimental facilities or providing access to national facilities such as accelerators, nuclear reactors, and synchrotron radiation source, to students and teachers from various universities. Nuclear Science Centre at Delhi, Inter-University Centre for Astronomy and Astrophysics at Pune and Inter-University Consortium for the Department of Atomic Energy Facilities with headquarters at Indore have already been set up and have been extremely useful.

Advance Centres for Science and Technology (ACST): A few senior scientists and industrialists have proposed setting up advanced centres for science and technology. These are composite science and technology education and research centres. They seek to integrate education and research, science and technology, pure and industrial research. These centres will provide a 5-year integrated programme leading to either an M.Sc. or M.Tech. degree. The students will be given a common course in the first year, aimed at ensuring good grounding in physical concepts, equipping them with mathematical techniques and statistical procedures and exposing them to the current excitement in life sciences. A large menu of courses will be offered in the second and the third year from which students can choose, in consultation with the faculty advisors, such courses that would suit their aptitude and abilities. At the end of the third year there will be a test conducted to assess students' aptitude and ability to pursue basic or applied research. The fourth and the fifth year will be for specialization in chosen fields. It also provides for an internship programme of one year in the related industry for applied stream students and in reputed research laboratories for basic science stream students. The faculty will be carefully chosen and encouraged to forge strategic alliances with the industry and will be expected to remain at the frontiers of science and at the cutting edge of technology. Another distinctive feature of the programme is that the beneficiaries of the products of the system, namely the industry, national laboratories, and government science agencies, will participate in the management, monitoring and funding of ACST. It is gratifying to note that UGC has included the proposal for setting up ACST in the tenth five-year plan.