Chapter 9

Science Education for National Development
Indian Perspective

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Prologue

Over the past six decades India has made a notable economic progress. The country which had a scarcity of food grains at the time of independence is now self sufficient in spite of the fact that its population has trebled during this period. It has a successful Atomic Energy programme designed for peaceful purposes. It can boast of a successful Space Programme with a capacity to build and launch satellites both in geostationary and polar orbits. India has emerged as an Information Technology hub in recent years with a huge export of software. The country now has a strong industrial base that produces a variety of consumer and industrial goods. The impact of global economic recession has been almost negligible on Indian economy. With a sufficient number of personnel trained in science and technology, it can take care of R & D institutions within India and can also supply trained manpower both to the developed as well as developing countries.

The success story described above can be attributed to a systematic effort to build human resource in S & T within the country. There are ten major things that have affected this resource generation task directly. They are:

1. Government Policies
2. Curriculum Development
3. Teacher Preparation
4. Educational Facilities in Science and Technology
5. Identification and Nurturing of Science Talent
6. Establishment of R & D Institutions
7. Facilitation of Industrial Growth
8. R & D in Science Education
9. Resource Generation
10. Spread of Scientific Literacy

We will now discuss each of these aspects in detail.

1. Government Policies

Soon after gaining independence in 1947 India embarked on self-reliance as well as sustainable and equitable growth. India has a long tradition of science and technology. By revitalizing its tradition it has committed itself to the task of promoting science and has recognized the key role of technology as one of the most important elements of national development (MIB, 2003). The first Scientific Policy Resolution was drafted in 1958. It was revised in 1983, 2003 and recently in 2013 taking into account the feedback and the needs of the countrymen. It would be useful if we go through some of the pertinent aspects of these policy documents.

Scientific Policy Resolution 1958

The policy resolution clearly stated that the key to national prosperity lies in combination of three factors: technology, raw material and capital, of which the first is perhaps the most important of all. But technology can only grow out of the study of science and its application" (DST, 2004a).

Technology Policy Statement, 1983

The basic objectives of the technology policy formulated in 1983 were to attain technological competence and self-reliance, to reduce vulnerability, particularly in strategic areas, making the maximum use of indigenous resources (DST, 2004b). It focussed on the use of traditional skills and capabilities, making them commercially competitive and to ensure the correct mix between mass production technologies and production by the masses (DST, 2004 b).

Scientific Policy Resolution of 2003

The policy framed in the light of the new millennium placed emphasis on ensuring that the message of science reaches every citizen of India and to provide food, water, health, and energy security for the people on a sustainable basis. In addition, it emphasized the need to vigorously foster scientific research in universities and other academic, scientific and engineering institutions; and attract the brightest young persons to careers in science and technology (DST, 2004c).

Science, Technology Innovation (STI) Policy

The new policy unveiled in January 2013 focuses attention on innovation (DST, 2013). Hence this policy is called Science, Technology Innovation (STI) Policy. The Key features of the STI policy 2013 are: 1) Promoting the spread of scientific temper amongst all sections of society, 2) Enhancing skills for applications of science among the young from all social sectors, 3) Making careers in science, research and innovation attractive enough for talented and bright minds, 4) Establishing world-class infrastructure for R & D for gaining global leadership in some select frontier areas of science, 5) Positioning India among the top five global scientific powers by 2020 (by increasing the share of global scientific publications from 3.5% to over 7% and quadrupling the number of papers in top 1% journals from the current levels), 6) Linking contributions of Science Research and innovation system with the inclusive economic growth agenda and combining priorities of excellence and relevance, 7) Creating an environment for enhanced private sector participation in R &D, 8) Enabling conversion of R & D output with societal and commercial applications by replicating hitherto successful models, as well as establishing of new PPP (Public Private Partnership) structures, 9) Seeking S & T based high risk innovation through new mechanisms, 10) Fostering resource optimized cost-effective innovation across size and technology domains, 11) Triggering in the mind-set and value systems to recognize, respect and reward performances which create wealth from S&T-derived knowledge, and 12) Creating a robust national innovation system.

2. Curriculum Development

For a long time, science education has remained a prerogative of only a few elites in the society. Science as a discipline of formal study received low importance in the schools established by kings and philanthropists in the pre-colonial period. During the British raj, efforts were made to teach science formally. However, these efforts were limited to higher education. At the school level science was meant only for extraordinarily brilliant students and for students with special interest towards science (Sharma, 1975). In the post independent period special efforts were made to ensure 'Science for All' and to bring in qualitative improvement in its teaching.

The first attempt to include science as a subject of study in school education was made by Secondary Education Commission (1952-53). The commission recommended teaching of simple principles of science to primary school children followed by a diversified course for high schools. Accordingly, General Science was taught to the students up to grade 8 and three disciplines namely Physics, Chemistry and Biology were taught to students who opted for science stream in grades 9 and 10.

The report of the Education Commission (1964-66) made a lasting impact on school science education in the entire country (Govt. of India, 1966). The report entitled "Education and National Development" laid great emphasis on making science and mathematics an important element in school curriculum and recommended teaching of these subjects on a compulsory basis to all the pupils during the first ten years of schooling. Accordingly, education departments of all the states undertook to implement this recommendation and included science as a core subject in school education until the school leaving stage (grade 10).

National Council of Educational Research and Training (NCERT) established in 1961 at New Delhi (the capital city of India), as an apex body in education, undertook the task of framing national curriculum for school subjects. Following the recommendations of the National Education Commission in 1966, NCERT came out with a National Curriculum Framework to teach science to all in 1968. The Government of India decided to take stock of the school education once again in the 1980s and published the National Policy on Education (NPE) in 1986 (Govt. of India, 1986). Instead of a discipline-focused curriculum, NPE suggested integrated approach of teaching of science where all its branches are taught in a coherent manner bringing out their interrelationships and their social relevance. Towards the end of the last century the Ministry of Human Resource Development (MHRD) of India decided to take a fresh look at school education. NCERT published a National Curriculum Framework for School Education in 2000 (NCERT, 2000). The framework highlighted the importance of integrating indigenous knowledge with school science curriculum and urged the educators to teach science in such a way that the future citizens of India are competent enough to meet the challenges of globalisation and of the growing importance of Information and Communications Technology (ICT). The recent National Curriculum Framework prepared in 2005 (NCF, 2005) goes beyond the classrooms and brings out the importance of out of school experiences. It also emphasises linking science and mathematics with life skills and highlights the need to inculcate values in the students.

3. Teacher Preparation

In addition to curriculum development, teacher preparation was given due attention in India. It involves pre-service as well as in-service training course for teachers.

Pre-service Training

Professional training along with basic qualification is mandatory for the job of a school teacher in India. Primary teachers are expected to get their Diploma in Education (D. Ed.) after Higher Secondary School Certificate (H.S.S.C.) examination. For teaching science at the secondary level teachers are expected to obtain a degree of Bachelor of Education (B. Ed.) after a degree in science. A large number of teacher training institutions have been established in the country in the post-independent period. It has increased to some thousands from a mere two digit number (43). They fall under three categories: Government-run colleges, privately-managed but Government-aided, and privately-managed and unaided institutions. The admission to these institutions is quite competitive. About 200,000 trained teachers come out of these institutions every year.

In-service Training

Through its pre-service courses teacher training institutions provide general background in education to prospective teachers. This imput is seldom sufficient to deal with changing curriculum and societal expectations. Practising teachers, therefore, need to undergo refresher courses during their service period. State Councils of Educational Research and Training (SCERT) in different states of the country arrange in-service training courses for science teachers. These courses are invariably conducted whenever there is change in the curriculum.

District Institutes of Education and Training (DIET) are being established to take care of educational needs of the district. In the last decade the central Government has supported establishment of about 450 such institutions. Some of them have become functional while some are at the stage of development. When fully operational, these institutions will serve as resource centres for elementary schools in their respective districts. They are expected to conduct teacher training apart from providing support to teacher education institutions within the district.

The NCTE

The National Council of Teacher Education (NCTE) as an advisory body came into existence 1973. It was then made a statutory body by the act of Parliament in 1993. The main aim of NCTE is to achieve planned and coordinated effort of teacher education throughout the country, the regulation and proper maintenance of norms and standards in the teacher education system and for matters connected therewith.

The mandate given to NCTE is very broad and covers the whole gamut of teacher education programmes. It is trying to maintain certain standards and bring in uniformity in the curriculum for pre-service training of teachers. In addition, it has initiated training programmes for practising teacher educators so that a large number of teachers could be trained on a regular basis. With its headquarters in Delhi, there are four regional branches to take care of issues at regional levels. A well qualified academician or an administrator heads these regional branches.

4. Educational Facilities in Science and Technology

In addition to school education, Ministry of Human Resource Development (MHRD) gave adequate attention to the development of institutions of higher learning so that a large number of students can take higher education in science and technology. University Grants Commission (UGC), an apex body looking after higher education in the country, was encouraged to start new colleges with facilities for science education. In order to ensure that students receive quality education in science, efforts were made to equip the college laboratories.

The Ministry of Education, later renamed as Ministry of Human Resource Development (MHRD) also initiated the establishment of institutions of higher learning to provide quality education in science. Four Regional Colleges of Education (RCE) were set up to teach science along with pedagogy. Setting up of Indian Institute of Technology (IIT) in the country can be mentioned as one such example in the context of technology education within the country. On the lines of IITs MHRD recently came forward to start institutions for science education called Indian Institute of Science Education and Research (IISER). These institutions attempt to provide quality education in science and prepare students to face the challenges of the future. The performance of these institutions has been quite encouraging so far.

5. Identification and Nurturing of Science Talent

Systematic efforts are being made to search and nurture science talent among young students. A brief description of these activities is given below.

National Talent Search Scheme

The National Council of Educational Research and Training (NCERT) soon after its establishment launched a programme to identify and nurture talented students. This programme took the shape of a scheme called National Science Talent Search Scheme (NSTSS) in 1963. It provided for the identification of talented students and awarded them scholarships. In the initial period, these scholarships were awarded for pursuing education only in basic sciences up to doctoral level. NSTS scheme underwent a change in 1976 and was extended to include social sciences, engineering and medicine as well. It was renamed as National Talent Search Scheme (NTSS). The scheme still continues under the name of National Talent Search Examination (NTSE). Apart from financial assistance, summer camps and seminars are also arranged for the awardees of the scheme. Over the last 40 years (1963-2013) a large number of students benefited from this scheme. Many of them could continue their education due to the financial assistance received through the scholarship. It has enabled the country to increase the manpower in Science and Technology to a considerable extent.

KVPY

A scheme called Kishore Vaigyanik Protsahan Yojana (KVPY) has been launched to encourage scientific creativity among post-school persons. Funded by the Department of Science and Technology (DST) of the Government of India, the scheme is meant to attract exceptionally and highly motivated students for pursuing basic science courses and career in research. The selected candidates are given generous fellowships to pursue their studies. The benefits of this scheme are yet to be realised. However, the feedback received from the field is quite positive. A large number of students in the country are experiencing positive fruits of these schemes.

Inspire Award

A new scheme was launched in 2010 by the Department of Science and Technology to tap the science talent existing in young students. The scheme popularly known as INSPIRE (which is an acronym of Innovation in Science Pursuit for Inspired Research) encourages school and college students to come out with innovative ideas in science. The scheme has three components: SEATS (Scheme for early Attraction of Talent), SHE (Scholarships for Higher Education and AORC (Assured Opportunity for Research Career). As the name suggests, the first part of the scheme (SEATS) attempts to attract talent at the early age (10-15 years). The students with potential are given financial assistance of Rs, 5000 each (about US$ 90) to convert their idea into a workable project. This financial support ensures that even indigent children have opportunity to demonstrate their talent. Once chosen for the award these students are given an opportunity for internship with practising scientists in the country. The second part of the scheme (SHE) is for the students with a little higher age group (17 to 22 years) who are pursuing their education in science or technology. The third part of the scheme (AORC) is for the students pursuing doctoral studies or for those who have entered into the profession recently and can be used by persons in the age group of 27-37 years. One can thus see that this scheme attempts to attract students at different ages to science-related professions.

Ignite Scheme

This scheme has been launched by the National Innovation Foundation of India under the Department of Science and Technology. It attempts to identify hidden talent from among the community. Children irrespective of their educational qualifications can submit the entries for this competition. The best entries are recognised and supported. This scheme has only started recently. Hence, its impact will be felt after a few years.

International Olympiads

Olympiad competitions are held internationally to spot the talent among students in specific subjects. In this context, competitions are held in science as well as in mathematics apart from other subjects like Informatics and Technology. Government of India decided to send the teams to science and mathematics olympiads and entrusted the responsibility of selecting teams to the Homi Bhabha Centre for Science Education (HBCSE), a national centre of the Tata Institute of Fundamental Research (TIFR) for science and mathematics education. Acting as the nodal agency, HBCSE has been identifying and preparing students for Olympiad competitions in Mathematics, Physics, Chemistry, Biology, Astronomy and Junior Science for the last decade. A large number of students from secondary and higher secondary schools appear for national level competitive examinations. Help is sought from teachers' organization like Indian Association of Physics Teachers (IAPT) to arrange examinations at the national level. Training cum selection camp is held at the premises of HBCSE in Mumbai. The performance of Indian teams in international competitions has been good. Apart from sending the teams to other countries, HBCSE has also hosted a few international Olympiad events like the International Biology Olympiad, and the International Astronomy Olympiad in the recent past. In addition to selecting the teams for international competitions this activity has helped HBCSE to work out the inputs required for the nurturing of talent. Participation in international events has also enhanced competitive spirit among the intelligent young lads (http://olympiads.hbcse.tifr.res.in).

Science Exhibitions

Organization of school level science exhibitions was initiated sometime in the 1970s to provide opportunities for innovative teachers and students to display their talent. After a slow start, the activity has now spread length and breadth in the entire country. NCERT suggests the theme of the exhibition every academic year and students from different schools are expected to prepare exhibits/working models pertaining to the theme. Starting from taluka level (small administrative block of a district) the exhibitions are arranged at district, state, national as well as at international levels. School teachers and other staff members of schools along with enthusiastic people for the community get involved in the organization of the event at different levels. They get good exposure to science ideas presented by participating students. Through this activity a large number of innovative ideas from school students and teachers have surfaced.

Along with NCERT, the National Council of Science and Technology Communication (NCSTC), Department of Science and Technology, Government of India also initiated a Children's Science Movement in 1993. Under this scheme, NCSTC arranges National Children's Science Congress (NCSC) annually for the children of 10 to 17 years from all over the country based on their research. The main objectives as advocated by NCSTC (www.ncstc.dst.gov.in) are: To provide a forum to the young scientists to pursue their natural curiosity and to quench their thirst for creativity by experimenting on open-ended problems: to make them feel that science is all around and you can gain knowledge as well as solve many problems also by relating the learning process to the physical and social environment of the neighbourhood and to encourage children throughout the country to visualise the future of the nation and help in building a generation of sensitive and responsible citizens. Over the last 20 years NCSC has taken a good step by involving a large number of teachers and students from both urban and rural schools. This activity has stimulated scientific activity among the students and enabled them to learn the scientific methodology of observation, collection of data, data analysis in order to arrive at conclusions and present the findings effectively. This mode of exhibition is offering an opportunity to the students to actually play the role of a scientist at school level. Majority of the students find it both challenging and enjoyable.

6. Establishment of R & D institutions

As a policy of self reliance, Government of India made deliberate efforts to set up new institutions for conducting basic and applied research within the country. Under the aegis of the Department of Science and Technology of the Government of India, there are a variety of agencies managing these research organizations. Let us have a look at some of the major agencies supporting research and development activities in the country.

Council of Scientific and Industrial Research (CSIR)

Council of Scientific and Industrial Research (CSIR) was established in pre independence period in 1942to provide scientific and industrial R & D that maximises the economic, environmental and societal benefits for the people of India. It presently has more that 50 institutions all over the country working in the area of basic and applied sciences. Some of the notable institutions of CSIR are: National Chemical laboratory, Pune; National Institute of Oceanography, Goa; and Centre for Cellular and Molecular Biology, Hyderabad (www.csir.res.in).

Department of Atomic Energy (DAE)

Department of Atomic Energy (DAE) was set up by the Government of India as early as 1954. DAE, as the name suggests, takes care of research and development activities related to atomic research. It presently has a large number of institutions under its purview which are categorised as Research institutions, Supported institutions, and Industrial units. Since the beginning the government of India embarked on the peaceful uses of atomic energy and the DAE has steered the programme successfully and has demonstrated capacity to manage Nuclear Reactors successfully. Over the past five decades DAE has emerged as an umbrella for basic and applied research within the country. It has embarked on technology transfer to the society as well as to industries (www. dae.nic.in).

Indian Space Research Organization (ISRO)

Indian Space Research Organization (ISRO) set up in 1969 takes care of activities related to space science. It works in the areas of satellite launching, weather forecasting, space explorations, etc. It has made available a dedicated satellite for education named EDUSAT. In addition, ISRO provides support to science education through its Cluster Resource Centre and Educational Portal (www.isro.org). The objective of ISRO is to develop space technology and its application to various tasks of national and international interests. Accordingly, it has successfully put into operation two major satellite systems, namely the Indian National Satellites (INSAT) for communication services and the Indian Remote Sensing (IRS) satellites for management of natural resources. It has also developed various launch vehicles, like the Polar Satellite Launch Vehicle (PSLV), the Geosynchronous Satellite Launch Vehicle (GSLV), etc. for launching satellites. Using these launch vehicles ISRO is not only launching Indian satellites but also offering services to other countries.

Indian Council of Agricultural Research (ICAR)

The Indian Council of Agricultural Research (ICAR) is an autonomous organisation under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. The Council is the apex body for co-ordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the entire country. With 99 institutes and 53agricultural universities spread across the country this is one of the largest national agricultural systems in the world. The ICAR has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development that has enabled the country to increase the production of food grains by 4 times, horticultural crops by 6 times, fish by 9 times (marine 5 times and inland 17 times), milk 6 times and eggs 27 times since 1950-51, thus making a visible impact on the national food and nutritional security. It has played a major role in promoting excellence in higher education in agriculture. It is engaged in cutting-edge areas of science and technology development and its scientists are internationally acknowledged in their fields.

Indian Medical Council (IMC)

The Medical Council of India was established in 1934 under the Indian Medical Council Act, 1933. It has a main function of establishing uniform standards of higher qualifications in medicine and recognition of medical qualifications in India and abroad. The number of medical colleges had increased steadily during the years after Independence. It was felt that the provisions of Indian Medical Council Act were not adequate to meet with the challenges posed by the very fast development and the progress of medical education in the country. As a result, in 1956, the old Act was repealed and a new one was enacted. This was further modified in 1964, 1993 and 2001. The objectives of the Council are as follows: Maintenance of uniform standards of medical education, both undergraduate and postgraduate, recommendation for recognition/de-recognition of medical qualifications of medical institutions of India or foreign countries, Permanent registration/provisional registration of doctors with recognised medical qualifications and Reciprocity with foreign countries in the matter of mutual recognition of medical qualifications. A variety of research is being carried out in preventive as well as curative methods in the country by this organization (www.mciindia.org).

With the strong financial support received from the government the above organizations have set up their wings all over India. A large number of young science graduates who come out of science colleges are absorbed in these institutions. These openings apart from encouraging future generation toward science also provide opportunities to do pioneering work in the field of their choice. As a result, the trained manpower in science and technology is being generated within the country in large numbers.

7. Facilitation of Industrial Growth

Over the past six decades there has been a notable growth in Indian industries. With the opening up of the economy in 1991, a large number of multinationals have made their headway into the country. At the same time Indian industries are making their presence felt in other countries. Some of the notable industrial areas are Auto-mobiles, Pharmaceuticals, and IT-based services. The manpower trained in educational and R & D centres are absorbed in these industries. They not only offer incentives to the next generation to study science and technology but also provide opportunities for further innovation and development.

Auto-mobiles

Auto-mobile industry in India has grown tremendously over the last few decades. To begin with, there were collaborative ventures. Slowly, however, home-grown auto-mobile products are brought out in the market. The presence of some of the well established auto industries in India clearly shows the growth in this area. Not only are they fulfilling the domestic demands but are also exporting the automobiles to other countries both developed as well as developing countries.

Health care and Pharmaceuticals

Health care industries have shown a tremendous growth in India. Medical tourism has now become good business for people in India as many of the hospitals in the country receive patients from other countries for medical treatment as it is both cheap and reliable. Likewise, the pharmaceutical industry has also seen an unprecedented growth over the past few years. Not only does it satisfy the need of the country but also supplies drugs to many other countries. It began with the multinational companies setting up their units here. Slowly, Indian pharmaceutical companies have also grown. Recently, there was a news item about an Indian pharmaceutical company manufacturing life-saving drug that is patented by a developed nation and selling same to the customer at one fourth of its price original price (TOI, 2012).

IT Services

India has seen tremendous growth in Information Technology (IT) sector which has has two components: IT services and BPO (Business Process Outsourcing). Growth in both of these fields has been significant. IT, thus, has become an employment and revenue-generating sector for the country. The growth of IT sector is still on and will contribute substantially to economic progress of the country. Apart from many multinational IT companies opening their offices in India, the Indian companies provide services to a large number of countries all over the world both developed as well as developing. IT export now forms a major source of foreign currency for India (TOI, 2012).

8. R & D in Science Education

A few decades ago science education was not recognized as a discipline for serious research in India. However, as the science and technology education took shape in the country some institutions started taking interest in conducting research in this field. NCERT has a special wing known as the Department of Education in Science and Mathematics (DESM) which conducts research in school curriculum, teacher education, and mode of evaluation. Four regional institutions of the NCERT and teacher training colleges, apart from preparing future teachers, engage themselves in research and development projects in science education. University Grants Commission has identified some of these departments as progressive institutions and has given them a status of Institute for Advanced Study in Education (IASE). They have a faculty and research students to conduct research in science and mathematics education.

Institutions engaged in scientific and technological research are also coming forward to undertake research and developmental activities in science and mathematics education. One such institution is the Homi Bhabha Centre for Science Education (HBCSE), established in 1974 as a constituent unit of the Tata Institute of Fundamental Research (TIFR), a national centre of the Government of India for Nuclear Science and Mathematics. Since its inception, HBCSE has been conducting research in curriculum development, teacher education, cognitive science, learning hurdles, etc. Based on the research findings, the centre has designed methods and material to be used by the system (http://hbcse.tifr.res.in).

The initiative taken by HBCSE had a contagious effect. A large number of educational departments started conducting serious research in science education. In addition, a few research institutions are thinking of following the footsteps of HBCSE and conduct research in science education. HBCSE has initiated a series of biannual international conferences to review research in science, technology and mathematics education. The papers submitted for consideration clearly indicates that a tradition of research in science education is emerging in the country.

9. Resource Generation

Science is an ever changing discipline. At the same time there are changes in the way science is being taught in classrooms. Hence, practising teachers require a lot of support in terms of resources for effective implementation of science curriculum. In this context a variety of programmes are undertaken to prepare supporting material for teachers. Like teachers, students learning science need supporting material to understand the concepts and appreciate the relevance of school science to daily life. Hence, supporting instructional material is prepared both for teachers as well as for students. Salient features of this material are described below:

Laboratory Kit

Science being an experimental subject needs to be taught through activities. However, the school laboratories are either non-existent or are inadequately equipped. In order to overcome this problem laboratory kits were designed by the National Council of Educational Research and Training and were made available to the system. Training courses were conducted to acquaint the teachers with effective use of the kits.. Using the kits the teachers could perform all the experiments prescribed at the primary level of schooling. For higher level financial aid was given to schools so that they could acquire necessary equipment for school laboratory.

The Indian school system is huge. Making available kits to all the schools or giving financial support to equip the laboratories of all the schools would demand huge sum of money. It was, therefore, thought appropriate to develop experiments using easily available materials. HBCSE through its field projects came out with a kit containing locally available things. This kit could be used for conducting all the experiments at primary and upper primary sages of education. A large number of training courses were conducted in different parts of the country to acquaint the teachers on how a laboratory can be built using easily (locally) available items.

Teachers' Handbook
Teachers usually have the same book that the students have in their bags. The need for additional material for teachers has been felt through various educational projects undertaken in different parts of the world. The importance of the handbooks for the teachers also has been confirmed through research projects. Efforts are, therefore, made both by Government as well voluntary agencies to prepare detailed handbooks to be used by the teacher. These handbooks provide inputs in a) classroom management, b) effective teaching of school science, c) assessment of students learning, d) assignments to be given to students for learning of concepts and e) out of school activities to support school science education.

Popular Science Books
With a view to explaining science concepts in a simple language to school students, some popular science books are prepared in large numbers. These books might take the shape of Science Quiz, Fiction or Non-fiction stories, Biographies of scientists and Answers to children's questions (Lagu, 1978). A notable aspect of these books is that many of them are written in local languages. It must be noted that there is a great demand to such books. State Governments encourage the writing of such popular books by giving away Best Literature Awards in Science and Technology.

Digital Resources
With the advent of technology it has become possible to design digital resources for teachers, students and parents to support school science education. In this context a programme undertaken by HBCSE is worth mentioning. Supported by the Rajiv Gandhi Science and Technology Commission, Government of Maharashtra, the project entitled Open Educational resources for schools aims at making available resources free of costs to all the stakeholders of school education namely, students, teachers and parents. At the national level the government of India has come up with a portal named 'Sakshat" that provides such resources in ample numbers. A low cost tablet (named Akash) has been developed that can access the digital material uploaded to the website.
In addition to resources on the website, the space-based resources are being used to support school science education (Bhatia and Joshi, 2006). A dedicated satellite named EDUSAT was launched by ISRO in October 2007. Being in the geostationary orbit, this satellite is available all the time for Indian people. Through this satellite two-way video as well as audio link has been made possible. It is useful in conducting teacher training and providing additional input to teachers and/or students in the context of school science education.

10. Spread of Scientific Literacy

In addition to teaching of science formally in the school system, deliberate efforts are made to spread scientific literacy among the masses through informal modes. Both governmental and non-governmental organisations are involved in this important task. Here is a brief account.

NCSTC

National Council of Science and Technology Communication (NCSTC) has been set up by the Government of India under the Department of Science and Technology (DST) to oversee the spread and popularization of science in the society (http://dst.gov.in/scientific-prograame/s-t_ncstc.htm). Towards this end, NCSTC undertakes a variety of activities like a) Research in thrust areas of science and technology communication, b) development of scripts, films, video and radio programmes, etc. C) Training school teachers and voluntary workers in science communication d) development of science journalists, e) Giving awards and recognition to outstanding science communicators, f) Coordinating with state councils and S & T networks, g) Developing capacity through science communication h) Arranging field programmes i) Organization of Children's Science Congress and j) Promoting international cooperation in science communication.

NCSM

National Council of Science Museums (NCSM), also established by the Government of India with a mandate of taking science to the doorstep of the society. Towards this end, it has set up science centres and science museums in different parts of the country. These centres/museums provide hands on opportunities to people to perform simple and interesting experiments. Apart from making available working models these centres/museums arrange science-based lectures and competitions regularly. Spread all over India, they have become a place of informal learning of science both for children as well as adults.

Voluntary Efforts

In India one finds a large number of voluntary agencies that undertake activities for popularization of science and mathematics. They often arrange popular lectures, lecture demonstrations, and question and answer sessions. They also occasionally arrange competitions like science/mathematics quiz and talent search examinations. More yeomen service is offered by these organizations through print material. For example, Kerala Sastra Sahiyta Parishad apart from bringing out a monthly magazine publishes books and pamphlets on relevant issues in Malayalam, an official language of the state of Kerala (Janardhanan, 2002). Similarly, Marathi Vidnyan Parishad in Mumbai brings out a monthly magazine and books with scientific articles written in lucid and simple Marathi (official language of the state of Maharashtra).

The Challenges

In spite of the fact that India has achieved a lot in developing S & T humanpower and in spreading scientific and technological literacy among the masses, it still faces a large number of challenges. It would be appropriate at this juncture to discuss some of the challenges and possible solutions.

Equity

Education is on the concurrent list of the state as well as central Governments. Although major responsibility of school education lies with the State Government, Central Government also runs some schools like Navodaya Vidyalaya (Model school for rural gifted children) and Kendriya Vidyalaya (school for the wards of the employees of the central government). Within the state, one finds four types of schools: i) Schools run by local Self-governments like the Zilla Parishad or Muncipal Corporation, ii) Schools run by the State Government Education Departments or Tribal Development Department (Ashram Schools), iii) Aided schools run by private organizations, and iv) Unaided schools managed totally by private bodies. One notices tremendous variation in the government-run, aided, and unaided schools. Firstly, the facilities in the schools are different. Secondly the clientele of these schools are also different. Students belonging to poor socio-economic status invariably attend schools run by local self governments. Those who can afford to pay heavy fees go to private unaided schools. Therefore, there is a great disparity in the educational opportunities available to the students. Achieving equity in educational opportunities, therefore, poses a great challenge. Studies were conducted at HBCSE to understand the difficulties faced by first generation learners and to design appropriate remedial measures. These studies revealed that lack of learning prerequisites, non-availability of educational opportunities and inadequate communication competence were responsible for the poor performance of socially-deprived students. Attempts made to compensate for these lacunae were found to enhance student's scholastic attainment in science and mathematics significantly (Kulkarni and Agarkar, 1985).

Hodson (2003) warns us that this is a time for action. Action will have to be taken to make school science curriculum relevant to the needs, interests and aspirations of young citizens. He also cautions us that if current social and environmental problems are to be solved, we need a generation of scientifically and mathematically literate citizens. To achieve this goal, these subjects need to be taught through activities and problem-solving assignments. Lack of proper resources in the school, however, precludes teachers from doing so. Some government as well as voluntary agencies took this issue on a priority basis. They developed low-cost kits along with manuals to use them effectively to perform experiments in the school setting. An educationally relevant laboratory programme has been designed and implemented successfully on a pilot level in selected schools (Agarkar, 1998). There is a need to undertake large scale programmes to implement activity-based teaching method in the classroom.

Teacher Training

India has a good and well-established institutional set up for providing pre-service training to the teachers. Even then, many of the schools do not have trained teachers to teach science and mathematics. It is imperative that training opportunities are provided to untrained teachers without delay. The Open universities and Open Schools in India are trying in this regard. Prospective science teachers are trained in subject content apart from educational psychology and classroom management. Science teaching is undergoing paradigm shift world over (Cheng, Tsui, Chow and Mok, 2002). It is important that prospective teachers are prepared to align with this shift effectively. Appropriate modification in the curriculum for pre-service education of teachers is called for. The role of a teacher is changing in the modern society. A teacher is now expected to be a knowledge manager rather than knowledge disseminator (Tan, 2001). Pre-service training is expected to prepare the teacher to play this role effectively.

Although some in-service training programmes are arranged both by government as well as non-governmental organisations, there is hardly any policy of training worked out for the entire country. The number of school teachers in India is more than 4 million (NCERT, 1998). It is almost impossible to train these teachers if we limit to direct mode of interaction. Instead, efforts will have to be made to design training modules for teacher educators who in turn would train the teachers (COMSEC, 1996). Encouraging teachers to undertake action research projects would probably help empower them to some extent. Provision for life-long education of teachers using modern technology has to be explored to prepare teachers to play leadership role in the future (Agrawal, 2002). Fortunately, the country has good IT facilities within the country. They need to be exploited for school education. This is the appropriate time to assure that space-based resources are used to improve the teaching of science and mathematics.

Research and Development

After a slow start, research in science and technology education has taken roots in India. Apart from government education departments, universities and research institutes are taking active part in conducting research and development activities in science education. They have a major responsibility to design methods and materials to improve teaching taking into account the constraints of resources in the schools. Heterogeneity of Indian classrooms poses challenges to the teacher. Research will have to be conducted to understand diversities in socio-cultural backgroundsof students and to progress through inclusive education. Another area of attention is assessment since the present mode of assessment entirely focuses on written mode which tests only the information. Proper evaluation methods are to be worked out to test skills and attitudes of students. Gender equity in science education is also an issue to reckon with. The task of academicians engaged in R & D work in science education in India is thus quite challenging.

Through various intervention projects, innovative methods of teaching are being developed. These methods when tried on a small scale are found to be successful. However, these innovations remain at the local level or die off as soon as funding ceases. There is, therefore, an urgent need to ensure that these innovations are critically assessed and implemented on a large scale. A central assessment body might be a good solution in this context. This body, apart from assessing the utility of innovations, should be encouraged to undertake research and development work in science and mathematics education. The tradition of conducting research in these areas is now well established in the country. What is needed is the continuous flow of finance and regular meetings of active researchers to achieve good quality research output.

Collaborations

Coordination among educational institutions, research organizations and industries is the need of the day. There has been some effort to develop links between educational institutions and industries in recent years. These efforts are to be strengthened so that people from industries spend time in schools and students in turn get an opportunity to work in industries. Similarly, organic linkages have to be established between educational and research organizations. This collaboration should be on an institutional basis so that a direct contact between scientists and students is established. This linkage should aim at exposing students to scientific research in their formative years (Limaye, 2006).

Epilogue

From the foregoing discussion, it is clear that the industrial and economic progress of India can be attributed to systematic use of science at all levels. The education system in the country attempted to prepare adequate manpower for R & D activities and for industries. Setting up of adequate number of R & D institutions within the country gave them opportunities to innovate. At the same time industrial growth within the country enabled people to practice those innovations leading to economic development. The Indian model of social and economic progress is, thus, based on the use of science. Any developing country can follow this model to achieve social as well as economic progress in a short time.

International cooperation in the field of science and mathematics education has proved useful in the past (Ramaraju, 1999). There is still a wide scope for international cooperation in this area at least at the regional levels. Collaborative cross-cultural research projects could be planned both with developed as well as with developing countries. Moreover, exchange of teachers could prove to be an effective way to acquaint them with global problems and solutions. The League for the Exchange of Commonwealth Teachers (LECT) under its Teachers' International Professional Development Programme (TIPD) has a scheme to arrange such exchanges. In this scheme, a team of practising teachers from one country spends extended period of time in another country to interact with teachers, teacher educators, and students. Such an interaction is found to be beneficial in enhancing teachers' professional knowledge apart from providing them first-hand experiences on how to tackle culture-specific problems in the classroom (Agarkar and Bedekar 2004). Arranging such visits frequently would certainly improve collaboration among educators from different countries.

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TOI (2012) The Times of India, March 14, 2012

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