between the ages of 9 and 16 could be provided special facilities and special instruction and resources of several kinds. It is important to realize that we must devote much more attention to these girls. It is very good that a decision has been taken to make women in general literate, but in my view, it would be far more profitable for India to spend the available resources on the girls i.e. the younger section of the female population. The special education that could be given to them will raise their image in society, empower them in several ways and above all, enable them to control their own pregnancies. Girls must be convinced that if they wish to have healthy babies they must produce them only when they themselves are mature enough to have good babies, i.e. when they reach the age of 20. They must be convinced that it is pointless producing babies that are inferior in both brain and body.

I think this programme of developing young women must be looked at carefully and quickly. We must provide large sums of money for developing and providing programmes for their education, specially health education with the specific aim of empowering them to control their own pregnancies and enabling them to have only healthy babies which they can do by having their first child at 20. As everyone knows simply enacting laws that prohibit them from marrying before 15 has not worked at all. How much money is required for these programmes. I think a sum of about Rs 30,000 crores to be spent largely on the young women of the BIMARU states as defined by Dr Ashish Bose could be considered a reasonable sum. Let people like Dr Ashish Bose and Dr Banu Coyaji under the umbrella of the ICMR be entrusted with the job of providing a model quickly – a model that can be modified (for different states) as one gains more experience.

All of us realize that we have a disaster looming before us with an unthinkable population size. We have a large unplanned population largely because we have neglected the young women, ensured that they continue to be our slaves for meeting our social and personal needs. We will continue to have unplanned children unless we devote all our attention to the young girls. The present state of affairs is the result of intellectual lethargy. I have often said that our post-independence intellectual classes are mainly lotus eaters, only wishing to take painless decision in order that they can carry on their lives in comfort, go abroad frequently for meetings and conferences, unperturbed by failures or having to take far-sighted decisions that could lead to failures. They are all good internationally inclined scientists, respectable committee men who never rock the boat. All these people have never been accountable for any decisions they have taken or not taken. Society must now insist on accountability before it is too late.

Science in India*

P. N. Srivastava

India's place in science and technology had its peak especially due to its pivotal position in mathematics and astronomy long before the era of Aristotle and Plato. Its textile had the global distinction. The age-old Indian philosophy, mythology and way of life have had ingredients of deep-rooted systematization of knowledge that are now rediscovered, reinvented by most powerful tools capable of probing the secrets of nature. Many famous authors of science fictions like Sir Arthur Clark do not hesitate to appreciate the great marvels of the ancient Indian scriptures. However, during the last 5–6 centuries, it has received a setback. As if to add to our handicap, the industrial revolution of the western world took place when India had been shackled under colonial rule. During the later part of 20th century extraordinary rapid growth in scientific knowledge coupled with technological innovation and expansion took place. When such extraordinary rapid developments were in motion, India attained its independence. At that time, in the name of technology, India had only a few obsolete textile and sugar factories and produced almost nothing of what the country needed. This was coupled with a stagnating agriculture.

A number of scientists feel that immediately after independence India should have taken the responsibility for research and development without having been unduly dependent upon or directed by any country or international organization. This possibly would have provided India with the competence not only to select the right kind of technology but also to define, innovate, execute and complete the whole processes successfully. Unfortunately this was by and large not done Even now, it is not too late. The strategies in the sphere of science and technology adopted by India should be to a large extent indigenous. It may, therefore, be necessary to

*Based on the Presidential address delivered during the 81st Session of the Indian Science Congress, Jaipur

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provide a new orientation for the development of science and technology and their application for socio-economic development.

There had always been a thinking that every country must have a scientific infrastructure, e.g. research centres, training institutions, laboratories, etc. and once such an infrastructure is available, technology will automatically develop as a consequential result of good science. This philosophy has worked well in many countries, both east and west, but has not given as fruitful a result as one would have expected in India. This aspect will be the basis of this article.

Before proceeding further, it will be pertinent to recall our achievements in many areas during the last 45 years[1,2].

Agriculture

In a predominantly agricultural country with growing millions of people every year, a failure or even a slower rate of enhancement of crop yields would not only have realized 'doom' predicted by Paddock brothers and the club of Rome but also severely damaged the progress in medicine, defence, atomic energy and all aspects of technology. Fortunately, the efforts of Indian agricultural scientists succeeded and resulted in 'green revolution' at about the same time when famine was being anticipated by the western world. While there should be no complacency at all, the fact is that India is better prepared today to face droughts than even before. In spite of three continuous drought years in the late eighties we did not have to import food. Today, we are in a comfortable position. However, we should also not forget that we had been singularly lucky in having six successive very good monsoons. A few bad ones might have caused undesirable setbacks although not serious famines of the magnitude experienced by some African nations.

Atomic energy

In atomic energy, we have achieved capabilities spanning the entire nuclear cycle, i.e. exploration, mining, extraction, purification and conversion of nuclear materials, production of fuel elements for reactors, design and construction of power reactors, reprocessing of spent fuel and waste management. More recently, the significant achievements include the operation of the 100 MW Dhruva reactor at full power since January 1988; commissioning of the 14 MeV Pelletron, one at the Tata Institute of Fundamental Research and the other under University Grants Commission as a central Inter-university facility in Jawaharlal Nehru University campus at New Delhi, the commissioning of the fast breeder test reactor; development work on advanced laser systems and synchrotron radiation source based on a 450 MeV electron storage ring; the initiation of the construction of giant metres wavelength radio telescope. During the last General Assembly of the International Atomic Energy Agency, Vienna, the Chairman of the Indian Atomic Energy Commission offered to export multipurpose nuclear research reactors and heavy water now being successfully produced in India to other countries under international safeguards.

From the review of the programmes in the science and technology scheme of the 7th Five-Year Plan, it has been noted that several important recommendations made in the report of the Steering Committee for S&T for the 7th Five-Year Plan did not get implemented in the manner originally envisaged. In several cases no initiative was taken to process the recommendations and thus many important areas were not even explored from the point of view of possible implementation. In the 8th Five-Year Plan, a recommendation has been made that all the recommendations be analysed and the plans may be converted into action. Let us hope that it would be done.

Space

Indian space research programme has made tremendous progress since the launching of small sounding rockets in 1963. The first satellite 'Aryabhatta' was launched in 1975; the multi-purpose satellite INSAT-1B in 1983 and INSAT-1C in 1988. The acquisition of the four band imageries from IRS-1A with a periodicity of 22 days had been on a regular basis since the start of regular payload operation in April 1988. Other significant achievements include the Augmented Satellite Launch Vehicle (ASLV)/Stretched Rohini Satellite Series (SROSS). The first development flight ASLV-D1 took place from SHAR in March 1987. The failure of the Polar Satellite Launching Vehicle (PSLV) in September 1993 because of certain minor deficiencies should not be considered a failure. It should not be forgotten that in such frontline areas there will be failures sometimes. One should not be disheartened by this. One always learns from failures as well. After all there is no other country which is going to help us in such ventures and we will have to stand on our own feet. I am sure that the experience we gained by our efforts will positively lead us to success. It should be considered a big step forward towards success.

Health

In the health sector too, the country has made notable progress. The infant mortality rate has been reduced from 140 per thousand to 95 per thousand; the longevity has increased from 32 years to about 60 years; small pox has been eradicated. The population growth too is slowing down and a few states like Kerala, Goa and Tamil Nadu have done extremely well. The birth rate of 42 per thousand in 1956 has come down to 32 per thousand. However, the coupling between research and health delivery system needs to be strengthened. The sub-centres, primary health centres, and community health centres have to be truly made functional.

Electronics and communications

Electronics and the associated areas of informatics, is one of the key areas of development in the world today. We have developed a wide base of capabilities in this field. There are major production agencies in the public, private and joint sectors several of which now have strong in-house R&D groups. There have been major developments in the area of professional electronics equipment and systems required in the field of defence, atomic energy, space science and technology, communications, civil aviation, etc.

It is a matter of pride for all of us that in case of Indian Air Force all of the equipment presently required for air defence, ground environment system consisting of radars of various types, troposcatter, cable and microwave communication links, complex data handling system are all of Indian manufacture, with the major part of it based on indigenous design and development.

Beginning with limited resources and limited manpower, the C-DoT achieved remarkable results within a short span of time. The development of systems like electronic PABX (EPABX), rural automatic exchange (RAX) and medium automatic exchanges (MAX) of 512 lines were assembled, tested and installed which are praiseworthy. Unfortunately, these developments have not been appreciated the way it should have been done and further encouraged.

Oil, natural gas and petrochemicals

In oil and natural gas sector there have been remarkable technological and manufacturing achievements across the entire spectrum of exploration and extraction; prognostic service; studies and investigations in deep drill exercise, both off-shore and on-shore; oil production techniques and pipeline facilities; design and manufacture of off-shore rigs and platforms; under-water technologies, etc. Off-shore oil exploration in the world is a high risk, high investment and high return venture. India's performance has been good and its plans for future exploration and production can prove to be the mainstay of our economy.

We should feel happy and proud of our achievements but under no circumstances become complacent. Many of us only go on talking about this and never refer to our shortcomings and weaknesses. This is similar to the way we talk about our civilization of about 5000 years. Our success stories should induce us to look into the areas where we have failed. India still has the largest number of illiterates in the world although we had decided that the universalization of primary education shall be achieved by the year 1960 in our constitution. According to the latest UNICEF report, two-thirds of the under-five year deaths are in ten countries with India topping the list. The performance of India in this respect is worse than Nepal, Bangladesh and Sri Lanka. India also tops the list of ten countries hosting the world's malnourished children while the number in China, Bangladesh and Pakistan put together is less than India. While it is true that India has done very well at the agricultural front, there has been some slowing down lately. It has been stated that while the standard of development relevant to the Indian field situation has been high, the same cannot be said of standard of science in disciplines cognate to agriculture. With all our complacency, let us compare our performance with China and other Asiatic countries. According to the Food Outlook Report of the FAO (1991), our per hectare rice production is 2624 kg, way behind that of China (5712 kg), and Indonesia (4301 kg). As far as wheat is concerned we produce 2125 kg per hectare, whereas China produces 3194 kg, European Economic Community 5118 kg and United States 2656 kg.

It has, no doubt, been very hard for developing countries in particular that even before they could cope up with the first industrial revolution of the 19th century variety, they were faced with the challenge of chemical technology, followed by microchip technology, biotechnology and the forthcoming technology of superconductors. The task has become very difficult because there has been a tremendous shortening of the time between the development of an idea and its useful application industrially.

During the last ten to fifteen years, the entry of computers into the ordinary houses in developed countries has sustained one of the fastest growing consumer markets. Their uses are limitless. Their applications arise from extremely low cost of microprocessors – electronic circuits provided in a tiny volume, the basic logical functions of a computer. Processing power of these components is constantly being increased, while at the same time their costs and size plunge down. Today, we see before us the information revolution and the coming of an information society. The information and communication technology make it possible to strengthen man's intellectual ability in a way that other revolutions could not accomplish. In years to come, however, software will prove to be an even more important problem. Software is in effect 'intangible material' and software technology will be crucially important to this area and deserves to be carefully and seriously nurtured. The maxim 'those who dominate materials dominate the technology' is being changed to 'those who dominate software will dominate the world'. Fortunately, India has the potentiality to be strong in this area

Having said all that, let us admit that although our performance has not been insignificant, it could have been better as stated earlier. Things indeed have gone amiss somewhere although we positively have had the capacity and capability to do better. It is a well known fact that our contribution to either the science or innovative technology of our times has been poor according to international standards. This opinion has been expressed by many scientists and technologists in India, Indian scientists and technologists abroad as well as foreign experts. Neither our numerous universities nor our big national laboratories can lay any claim to anything much more than some footnotes in the vast annals of discovery and invention. While a casual observer could easily believe that India has arrived on the world scientific scene, a critical observation, coupled with an honest reckoning with reality, would shatter this illusion. Rather, it seems that our large investment has to a good extent built a large establishment. A large establishment by itself does not guarantee scientific progress. In fact, scientific progress in India has been hampered, and has never enjoyed periods of rapid growth. In developing the theme of excellence and accountability, the subtle distinction between science as a pursuit of knowledge and its application for technological benefits has been kept in view. There is no doubt that application of science for the production of technology *per se* is also not a mean job and there we have done much better than in basic science. The production of technology is extremely necessary for the development of any country. And in many areas, as I have already mentioned above, many departments have done commendable job.

While it is true that scientists have not failed the country, we just cannot yet satisfy the nation only by repeated assertions what science has done. The questions are being raised today and these are very valid ones, whether Indians have misplaced their goals of science. There has been a naive enthusiasm for doing what everyone else is doing in the West without having goal-directed activities especially needed for our country. There may be lessons to learn from China! Accountability should put the onus on both the scientists and administrators to vindicate their positions, demands, decisions and actions. It is also being alleged and not without reasons that there is a lack of clearcut plan of action imbued with a sense of purpose.

Given the direction and financial assistance, India can become independent in various areas of science and technology of immediate relevance. India's indigenous cryogenic rocket engine programme has made some progress and the Indian scientists will be able to develop this within a couple of years. How nice would it have been if we had embarked on such an endeavour a few years earlier! The same is true about supercomputers. The work done at Bangalore in the National Aeronautical Laboratory deserves praise. The difficulties that we had faced in buying Cray supercomputer for the Indian Institute of Science, Bangalore are very well known. The Centre for Development of Advanced Computing (C-DAC) set up in 1989 with an investment of Rs 30 crores has today opened a new technology with export potentials. It is fortunate that the same amount of Rs 30 crores had not been spent just to buy one Cray computer. The result is before us. It very clearly shows that given proper direction, facilities, the Indians can do whatever is needed for the country.

There has been a serious lacuna that a truly critical and unbiased assessment of our track record has never been made, be it of national laboratories including atomic energy, space research, or universities, etc. Is it not possible to do this with the help of some of our own Indian scientists working abroad, who may have no axe of their own to grind in India? This, of course, will not be the most ideal solution; further, a number of very meaningful reviews have been done by scientists from within the country, but, unfortunately, their many useful and meaningful recommendations have been scuttled on one pretext or the other. Obviously, vested interests dominate. But at the same time if extensive, unbiased and critical reviews have to be done, we will have to take the help of our scientists working both in India and abroad to take up this responsibility.

Scientific laboratories, governmental agencies and administration necessarily have a tendency only to paint a rosy picture of their successes and de-emphasize the failures in their Annual reports. Perhaps it should be made incumbent upon these organizations to put on record their shortcomings as well and their own perception as to how they could be overcome.

There are a number of bottlenecks in our system by way of rules and regulations, cumbersome working procedures and red tapism; these need to be removed. However, it is equally unfortunate that these drawbacks are generally not highlighted. During the last few years, a number of changes have been brought about in the procedures but the process is very slow and perhaps the truth is that the scientific administrators themselves may not be willing to let power slip off their hands.

It has been rightly and repeatedly pointed out that we have very few peaks of excellence both in terms of men and institutions. This is not only because of insufficiency of funds and facility alone. It is partly because of the depressing atmosphere that scientists have created for themselves in their scientific endeavour. We very easily compromise with mediocrity. The primary responsibility of promoting excellence is that of scientific community itself. They themselves must recognize excellence as something precious which requires the entire efforts of the community to collectively nurture and not something to be destroyed through envy and jealousy for petty considerations of individuals and groups.

It was very fortunate for our country that our first Prime Minister, Pandit Jawaharlal Nehru had very good understanding of science. While addressing science academy as far back as in 1938, he said.

> Who indeed can afford to ignore science? At every turn we seek its aid and the whole fabric of the world today is of its making. During the ten thousand years of human civilization, science came in with one vast sweep a century and half ago, and during these hundred fifty years it proved more revolutionary and explosive than anything that had gone before. We who live in this age .of science live in an environment and under conditions which are totally different from those of the pre-scientific age. But few realize this in its completeness and they seek to understand the problems of today by a reference to a yesterday that is dead and gone.

In particular context of India, he expressed his feelings so beautifully:

> If the new currents of renaissant India go along lines that are not the lines of science, then they too will go into a blind alley. Therefore, it becomes essential that the two must march together.

With the great affection, strength and authority given to him by the people of India, Pandit Nehru set about to lay the foundation of a vast number of institutions which, in the long run, were expected to turn India into a just and prosperous society.

And perhaps the most important of all was the building of the scientific and technological infrastructure which has grown to such immense proportions. It is very well known that his idea for the establishment of these institutions was in close collaboration and association with the universities in India. Unfortunately, it was not implemented in the way he thought in the beginning. When the plans of our future were being drawn up, science *per se* had little part to play; its role was almost entirely usurped by technology. And when people like Shanti Swarup Bhatnagar started setting up national institutes totally independent of universities, the obvious negation of Nehru's grand vision of science and technology had probably not been foreseen. History of science in India would record that intentions were for excellence, but steps taken have not been conducive to achieve the same.

On the heels of our independence, therefore, came the era of 'science and technology' more of technology and much less of science. The result of this alleged devotion to 'science' which was actually a devotion to developmental technology did result in beneficial effects for the society, from the immense psychological boost provided by the explosion of a primitive atomic device to the availability of so much of modern gadgetry. However, it had one most unfortunate consequence. Many of the outstanding scientists like C. V. Raman, S. N. Bose and M. N. Saha were totally alienated from the national science efforts. They believed that the government of India, in particular its helmsman, Jawaharlal Nehru, was primarily interested in pushing technology and that irrespective of his expressed sentiments and sensibilities (on science) he could not (or would not) extricate himself from the influence of his technology advisers.

Soon after independence, when the technology advisers of Nehru went to UK and USA, it was impossible for them not to be dazzled by the Manhattan project which culminated in a blaze 'brighter than a thousand suns'. There were a lot of 'highly visible' government R&D organizations which had made outstanding contributions to the war efforts and which employed (or had until recently employed) the most creative and best scientists available from the universities. The effectiveness of the scientist to 'deliver' was proved beyond question. Well-known scientists presiding over large high-technology projects was quite the 'in thing' those days. Scientists had tasted power for the first time in modern history, and some of them got addicted to it. Time has shown that this development was transient both in UK and USA but in India government-controlled laboratories were established away from the universities and the government scientists became our models. Our laboratories and organizations were developed and named after their British counterparts. When we sought advice from foreign experts it was from people like P. M. S. Blackett, who was a major figure in the British war efforts and was, at that time, presiding over a vast technology empire in UK. The emergence of the giant government laboratories in the West was entirely due to the war and the scientists returned to the universities once the task was accomplished.

The original idea of Nehru that the scientific institutions and laboratories should be established in close collaboration and cooperation with the university system was thus defeated and not implemented. The pay scale of scientists in the national laboratories was higher than those provided in the university system and, therefore, many good scientists migrated from the universities to the national laboratories. It was realized in the sixties itself, that the policy was counter-productive because it tended to dry up the very source of high class manpower from which national laboratories drew their sustenance. It has been shown that merely doing research without continued interaction with young enthusiastic students is bound to become stale after a period. This shortcoming has not been corrected yet.

On the one hand, well-staffed and well-equipped scientific institutes flourished and on the other, science and scientific thinking in the universities gradually deteriorated. Universities have multiplied but have only become inefficient graduate-producing machines. PhDs by the hundreds are being produced, specially after the introduction of the rule that a PhD is necessary for promotion.

After creating the super-scientific institutes, no thought was given as to where from young scientists will come. While constructing the beautiful first floor, the ground floor was forgotten. The universities began to languish due to lack of support and lack of leadership. In the meantime, the universities themselves were on their downward path due to stress on quantity than quality and the invasion of the concept that administration is better than science. Thus India produced many MScs and PhDs inducing us to make a spurious claim that India has one of the largest manpower of scientists in the world.

Expenditure in science and technology

The expenditure in S&T has increased from Rs 20 crores in the First Five-Year Plan to Rs 67 in the second; Rs 144 crores in the third to Rs 373 crores in the fourth plan. There were subsequent boosts in the expenditure starting from the Fifth Five-Year Plan. It was raised from Rs 373 crores in the Fourth Plan to Rs 1381 crores in the Fifth Plan; Rs 3716 crores and Rs 8487 crores in the Seventh Plan. In the VIII Five-Year Plan, the nation had committed approximately 2% of the public sector plan outlay, i.e. approximately Rs 9177 crores for S&T activities. Of this roughly half of the resources were allocated for the application of S&T in the 24 socio-economic ministries as categorized by the Planning Commission. Of the rest about half had been earmarked for the six major S&T departments for fostering and promoting S&T in the country.

Investment in science and technology with regard to the percentage of the GNP increased from 0.23% in the year 1958–59 to 0.39% in 1965–66; 0.47 in 1970–71; 0.60 in 1975–76; 0.66% in 1980–81; 0.70% in 1981–82; 0.79% in 1982–83; 0.78% in 1983–84; 0.93 in 1984–85; 0.96 in 1985–86; 1.11% in 1986–87 and 1.13% in 1987–88. This figure has unfortunately been reduced to less than 0.9% at present. As against this, the amount spent in other countries happens to be 2.7% in USA, 2.8% in Japan, 2.6% in former FRG and 2.4% in France, of the gross national product.

A moot point often made is that India has the third largest scientific and technological manpower in the world. When this point is made the population of India is conveniently forgotten. Our position has now become second; not because we have done anything remarkable but because the former USSR has split up into many states. When this figure is based on how many per thousand, then it comes to 4.5 per thousand for India and 111.14 for Japan; 262.4 for Sweden; 184.8 for Canada and 77.84 for the former FRG. As regards the number of persons involved in R&D, the figure for India comes to 0.27 per thousand population (1991 figure) whereas the figure for other countries comes to 5.24 for Japan (1984 figure); 5.41 for Sweden (1981 figure); 2.10 for Canada (1982 figure); 4.44 for France (1979 figure) and 3.96 for the former FRG (1981 figure). Where do we stand in such comparisons?

It may be worthwhile to analyse some of the relevant statistics[5]. The annual investment on R&D activity attained a level of Rs 4186.43 crores during the year 1990–91. It is a matter of regret that it comes to 0.89% of the GNP while we had reached about 1.1% in 1989–90. In the institutional sector, about 14% of the total expenditure was spent on basic research, 39% on applied research, 35% on experimental development and the rest 12% on other supporting activities during 1990–91.

Basic science doctorates had a share of 71% of the total 4372 S&T doctorates produced by the educational system in the country during 1989–90.

In 1990, the developed countries accounted for 96% of the total expenditure for research and development in the world. This figure was 95% in 1985 and 94% in 1980. Most of the developed countries devoted 2 to 3% of their GNP on R&D while India has spent 0.89% of GNP on R&D during 1991–92. India's per capita R&D expenditure was only a mere $2.76 whereas this was between $100 and $600 for most of the developed countries.

77.4% of total R&D expenditure of the major scientific agencies was consumed by five agencies: DRDO, ICAR, DAE and CSIR in that order with DRDO accounting for a share of 27.5%.

As far as the number employed in R&D sector was concerned, their number comes to 3.01 lakhs, of which 1.06 lakh were employed directly in R&D.

It is rather sad and tragic that the percentage share of S&T enrolment in India has been static at 29.3% since 1985–86.

Out of total of 8521 PhD degrees awarded during 1989–90, 3110 doctorates were from pure science.

During 1988–89 there were 2.49 lakhs of teaching staff in all faculty in higher education sector, out of which 2.6% consisted of professors.

Out turn of S&T personnel increased from 170,129 in 1978 to 220,762 in 1987. The percentage share of out turn of engineering and technology increased by 2.4% during the period 1978–87.

Besides the increase in nominal terms, R&D expenditure has also increased considerably in real terms. Assuming a 10% inflation, it has more than doubled during the first ten years from 1970–71 to 1980–81 and nearly doubled over the next six years during 1980–81 to 1986–87. Between 1970–71 and 1986–87, over a period of sixteen years, the increase in R&D expenditure is 19 times in nominal terms and about four times in real terms. As against this, the per capita expenditure in higher education has been reduced and today, in real terms, we are spending perhaps 50% of what we were spending in 1950–51.

During the Seventh Plan (1985–90) the Planning Commission had approved an expenditure of Rs 5213 crores for S&T activity. This amounts to 2.3% of the total public sector plan outlay. Out of this about 50% of the outlay was allocated to the scientific departments and another about 50% was allocated to 24 socio-economic ministries, such as irrigation, energy, health, housing and transport, etc. for improving productivity and efficiency of these sectors through S&T inputs. It is necessary to know how this amount has been utilized by these socio-economic ministries. In the VIII Plan as well almost the same percentage of public plan outlay has been kept for science and technology although the amount has now come to about Rs 9177 crores.

National Policy of Education, 1986

The new education policy was formulated during the 7th Five-Year Plañ. Many of the elements of this policy and the programme of action have a direct bearing on S&T education and should be pursued with vigour during the 8th Plan. A general recognition that teaching and research must go together, and going to the extent of suggesting that, from now on, all the major national laboratories of science should be set up within, or in cooperation with, teaching institutions. The philosophy had been there right from the very beginning but had never been implemented. This deviation between plan and practice had been noticed since early 1960s but has never been corrected; and in fact money continued to be poured into the existing laboratories which hardly had interactions with the university system. The proximity alone, however, does not ensure a closer interaction. It is not at all uncommon that some of the national laboratories which have been located in the university campuses not only do not interact with and extend facilities to the university laboratories but also develop inharmonious relationship. Rivalry and mutual bitterness result. The parties concerned are aware of these but nothing is being done. It should not be forgotten that there is a definite positive correlation between inputs and performance.

It is clear that the 8th Plan must recognize centrally that there can be no excellence in S&T without excellence in S&T education, and science and technology in education. The input into the education sector in science and technology has been regretfully small. For example, the COSIST programme during the 7th Plan was enhanced to Rs 40 crores but what is this Rs 40 crores for 180 odd universities and about 1000 science departments.

Referring to the Prime Minister's observation in the Science Congress last year that the decision-makers should do some heart-searching whether S&T has really been pressed into service of the country as well as ought to have been, I would suggest that the 24 socio-economic ministries such as irrigation, energy, health, housing, transport (which receive nearly half of the total allocation for S&T activities), should bring about linkages with societal needs in their activities. These close connections and linkages must have clear-cut and well-defined objectives and time-bound targets. These socio-economic ministries should be accountable to the nation for fulfilling the societal needs to which the Prime Minister had referred last year. It has been our experience that in fields of agriculture, atomic energy, space, etc., whenever definite goals have been set, the S&T community has succeeded to a good extent in delivering the goods.

It was suggested that during the Eighth Plan about 100 colleges selected from all over the country should be supported in a special manner so that bright science students have an opportunity of getting in-depth science education. About a dozen universities should be supported to conduct 'integrated science education programmes' starting from undergraduate level right up to the Master's degree. These recommendations had been rather forcefully forwarded by many scientists working in the universities, but has perhaps not been accepted.

Several of the national laboratories are engaged in basic research in science and engineering on topics which are also pursued in several Indian universities. These laboratories are relatively affluent both in terms of infrastructure and staff, compared to several universities. A recommendation has been made that on a selective basis, they may acquire the status of deemed university and be authorized to give degrees[3]. However, it must seriously be looked into whether these national laboratories were started for such a purpose. Are we not deviating from the aims and objectives of these national laboratories? It is surprising that such a recommendation has come from a body of senior science administrators and policy makers who are least connected with education. Should this be done, the last nails on the coffin of the already moribund university system would have been driven.

It may take a long time to make conditions in India comparable to those obtained in developed countries, but at the same time steps must be taken to induce our best talent to remain in the country and also to try to get back those who are abroad. The Scientists Pool of CSIR should be made attractive by offering better remuneration according to merit and by proper placement in right institutions. It is rather sad that, in general, Pool Officers have not been given the facilities and treatment that they deserve. If the scheme has to succeed, then they will have to be given better consideration and facilities with independence to do their research and should be provided with adequate funds for this. In the absence of this, the scheme is not going to succeed the way it was intended and the scientists would feel frustrated. However, it has to be admitted that the scheme has been very useful in giving opportunity to many scientists to do something while awaiting proper placements.

Basic research

The problem of basic research involves many factors, including financial inputs. Greater attention has to be given to this element during the coming decade. Although for the last 40 years, the government has made major efforts in promoting S&T, a review will show that its impact especially on basic research is not readily discernible. Major support for basic research generally comes from DST, CSIR, DAE, DRDO, DBT, etc. UGC and the Ministry of Human Resource Development have also initiated programmes for strengthening the science and technology infrastructure in the educational institutions. UGC has been supporting basic research, but in terms of funds, it has been no more than like a drop in the ocean. Very little basic research is being carried out by industries. This is yet another sad situation.

Basic research can thrive in an atmosphere where the creative and professional capabilities of the scientists are maximally centred and encouraged. The dynamic functioning of academic and professional bodies in the country can help in increasing the critical assessment which are important for quality as well as dissemination of research work. The universities in India, unfortunately, are very rigid and it is very difficult to bring about a change in their functioning. If basic research has to be promoted in India particularly in higher education, greater attention will have to be given to provide infrastructure facilities such as libraries, access to information, computers system, instrumentation, stable water and power supply and rapid availability of high quality chemicals and biological materials. In most of the newer universities established by the Centre as well as in some of the states, undergraduate teaching has been removed from the university system. This has been a major mistake. Youth especially of about 17 years or even slightly earlier should be brought into direct contact with eminent scientists who trigger the sparks in their minds. In most of the major universities in India a few decades back, BSc classes were always engaged by the eminent science teachers. Unless there is a continuous input of young people with originality and bright ideas into science, it would be unreasonable to expect major advancement in basic research. Conceptualization and execution of this important aspect cannot be done in any one of our national laboratories.

According to the DST report, of the Rs 3300 crores invested in S&T, only about 6%, that is, approximately Rs 200 crores had gone to the educational institutions. Even out of this, more than half of the money goes to only a few institutions such as TIFR, IISc and a few universities and thus the major university system, may be to an extent of about 80–85%, is being constantly deprived of infrastructure and facilities for teaching and research in science. The idea that at least 100 institutions in the country should be developed in the 8th Five-Year Plan to strengthen undergraduate teaching is extremely good. For this major support is necessary but I wonder if this will be forthcoming.

There is a basic need for the development of a number of centres (along the lines of the International Centre for Theoretical Physics, Trieste, Italy and the Institute of Advanced Studies, Princeton) specialized in certain areas of research within the university system. Some facilities have been created in places like the Nuclear Science Centre, New Delhi and the Inter-University Centre for Astronomy and Astrophysics at Pune. Many more centres in other disciplines should be started in the university system.

In a Seminar on Aesthetics, Economics and Status of Basic Science in India, organized by the Indian National Science Academy in early August 1993, the scientists concerned rightly expressed their anguish at the decline in funding situation in the country. The funds have declined from about 1.1% of the GNP to about 0.9% during the last two years. The detrimental impact of this is already being felt and the damage would reach irreparable proportions unless rectified on war-footing. In this seminar the scientists also expressed their dismay and concern about not having been consulted since the Scientific Committee to advise the Prime Minister or the cabinet did not exist for the last two years or so. However, it will be pertinent to ask whether these committees have made efforts at all to focus on the importance of teaching and research in the universities. No doubt these committees have had existence for more than 25 years. It is of course true that they occasionally expressed their anxiety about the deteriorating situation of science teaching and research in the university and colleges but it has always been only a lip service and never strong and persistent with recommendations on how to bring about improvements. Whenever the question of funding was raised the invariable argument had been that since the resources had been limited, the allocation had to be restricted only to the national laboratories and a few select institutions in the country. I am of the view as also several of my fellow-scientists that greater emphasis should have been given to provide funds for teaching and research in the science departments of the universities which are indeed the centres of learning and dissemination of knowledge. It is heartening to learn that the government has recently set up a Cabinet Committee on Science and Technology and an apex body called the Science Advisory Council to the Cabinet on Science and Technology (SAC-CCST). Let us hope that this body shows greater seriousness towards science education or, as earlier, looks only at strengthening the tip of the pyramid forgetting the base.

One of the senior scientists, who has been a member of the Scientific Advisory Committee to the Prime Minister, has frankly stated that during the 25–30 years of his service, he obtained allocation of budget by persuasion, manipulation, arguments or by lung power.

He further stated that unfortunately during all the experience of his life nobody asked him about the utilization of the facilities provided to him to the maximum or about the creation of greater facilities. He finally contended himself that everybody wanted to safeguard one's empire. Budget allocations were made across the table and there was no discussion. There are heated arguments and inflated demands ending up either in compromise or unrealistic allocations. If someone gets the money he has asked for then normally no questions are asked on goals because these are only the means to get money and not the ends! Both the receiving side and the giving side are happy and the final allocation for a department or institute does not take into account the accountability aspect[4]. This is really the tragic description of how allocations are made and utilized without anyone asking any questions. How many of the senior scientists in the country will be interested in changing this state of affairs? In such a situation, why and how should anyone feel concerned what happens to the question of teaching and research in universities!

C. N. R. Rao also emphasizes that basic scientific research is absolutely critical in building a technology base. This itself is weak for want of high calibred manpower. For instance, every year scientists from all over the country produce just 60–70 good research papers in the frontier areas of physics and chemistry. On the other hand each Department in an American University produces several more such publications. The pertinent question to be asked should be whether such a result was not to be expected when the educational institutions and universities are largely deprived of funding for teaching and research.

Science education

The Americans are concerned that science education in their country in the recent years has lagged behind some countries in Europe and Japan, although they are still much more advanced and much more superior than many in the world. They are not complacent but feel concerned about this[9–14].

It is being very seriously discussed in the US that the need to improve science education should be a national priority. Ways are being suggested by which the Federal Government and the scientific community, working together, should address this issue. It is recommended that scientists, engineers, and educators make a significant personal and institutional commitment to participate in science education activities, and that the President of the US provide the personal leadership to generate a national commitment to the improvement of education at all levels. Have our own scientists in India as well as our political leadership ever shown such a serious concern?

The Americans feel that in certain high-tech areas, the Japanese and the other emerging 'Asian Tigers' (which does not include India) have already made a greater impact, and that advantage continues to grow. The Japanese now control more than 50 per cent of the world's semi-conductor industry and about 90 per cent of the world market in dynamic random access memories, which some argue are the guts and muscle of the microchip industry; in 1986 the US showed a trade deficit in high-tech areas for the first time. Looking to the year 2000 and beyond, they seem to be apprehensive that they might face a serious problem in terms of numbers of individuals who can contribute actively to the fields of science and engineering. They are concerned not only about attracting and retaining more students in the areas of S&T, but also about the quality of education being received by all students. They feel that if the comparative performance of American students relative to that of their peers in other countries has to be retained then a great deal will have to be done in the area of science education at all levels.

The United States educational system which they consider was a model of flexibility and comprehensiveness for meeting the manpower needs of industry at mid-century, is failing badly in preparing today's work force. They consider that broad-based educational reforms must be the basis for science policy reform. Thirty years ago the US improved education in science and engineering in response to the Russian Sputnik challenge. Today, their high school students are considered to be doing dismally in international comparison of skills in mathematics, science and foreign language. In pursuance of this worrisome concern, apart from inputs in higher science education, the basic changes have been brought about in their school system as well. More than 40 states have raised their requirements for high school graduation, and 19 added a minimum-competency test to their requirements. Forty-six states mandated competency tests for new teachers. States also raised teachers salaries dramatically, with top pay surpassing $50,000 a year. Starting salaries improved too taking the rate of inflation into consideration and now averaging around $24,000. This is bound to exert a tremendously favourable effect on the entire school education. This shows the care and concern which the United States is now showing towards science education.

Let us now briefly examine as to what Japan has done during the last hundred years. It was towards the later part of 19th century that they thought of universalization of primary education. In Japan, today, education up to twelfth class has almost become universalized. About one-third of the students going for higher education go in for S&T. The expenditure on education in Japan comes to Yen 545,000 per student up to twelfth class and Yen 1,660,000 per student for higher education (1983 UNESCO figures). No country in the world is spending on education as much as Japan is doing. The success of Japan, therefore, is a story of decades of seriousness and investment and not that of a few years after the second world war.

As against this, let us consider what our senior scientists recommend to the Government (*Perspectives in Science and Technology*, 1990 vol. I, pp. 15–16)[3]:

Initiate a programme of providing excellence in science education by establishing consortia of universities that can work in collaboration with higher institutions of learning, such as TIFR, IISc, the IITs, etc. utilizing their superior resources, both human and material.

Initiate immediately postgraduate programmes in certain special areas of engineering and technology (such as mathematical modelling, computer simulation, materials technology, materials processing, polymer technology, etc.) at some of the national laboratories which may be given the status of deemed universities for running such programmes.

Establish joint centres (along the lines of the CNRS in France) run by national laboratories and universities together to provide better research and developmental facilities to the university sector.

Promote centres of excellence in universities around gifted scientists and engineers, individually or in small groups, and provide them with flexibility and a degree of autonomy from the university administration, which is often not sensitive to the needs of research. Even in the higher institutions, the quality of infrastructural support now available leaves much to be desired, and should, therefore, be improved.

Create advanced centres for research to be named after Jawaharlal Nehru to commemorate his birth centenary.

Grant autonomy to science and engineering colleges with a proven track record.

Provide large scale funding for improving institutional infrastructure of universities and other educational institutions as well as selected science and engineering colleges.

Introduce innovative ways of training competent manpower for frontline areas of S&T (e.g. short-term training in chosen areas in identified institutions abroad).

As human and technological skills are the key to the creation of greater national wealth, take steps to ensure that such skills are commensurately rewarded.

The serious question to ponder over is as to where do these recommendations stand in comparison to the concern being shown towards all levels of education in the US. I wonder, how a few extremely limited number of institutions like TIFR, IISc, the IITs and a few universities could meet the requirements of India in the 21st century? How do we then fulfil the dreams of Jawaharlal Nehru, who had said that: 'we should produce high class scientists, who would be as good scientists as from any other part of the world, who would stand up to the best in the world with them. We do have some such persons amongst us, and it is with their help that we have achieved whatever we have. But one or two, or for that matter ten or twenty of such scientists, are not sufficient. We require them in thousands and more. Only then, will our country prosper.' Will the dreams of Jawaharlal Nehru and the needs of the 21st century be ever met, even if the recommendations of our scientists are implemented the way they have been done? If at all we are concerned about achieving something in the 21st century, it will be absolutely necessary for our Government to fulfill the promise given in the parliament that from VIII Five-Year Plan onwards a minimum of 6% of the GNP will be allocated to education. This was adopted unanimously by all the political parties but we have still far to go to reach that level. It would be extremely necessary that about ten per cent of our S&T budget should be earmarked for training of manpower in universities and colleges. I wonder why the scientific activities of the University Grants Commission should not be supported by various concerned agencies and departments in S&T. Why should this responsibility be only of the Ministry of Human Resource Development alone, whose allocation in any case is not as good as that of science and technology. Proper improvement will have to be made in primary and secondary schools as well. If we do not do this, we will only be strengthening the tip of the pyramid which we have been doing for the last forty years. In such a situation we will never be able to compete with the world in the 21st century.

The vision of Rajiv Gandhi was, in his own words: 'I too am young. I have a dream. . . . I dream of an India, strong, independent, self-reliant and in the front ranks of nations of the world. . . . I look forward to our scientists accepting this challenge and bringing India ahead of most of the developed countries in certain fields and gradually in all fields.... Let us get on with the objective of making India great.'

The Minister of State for Science and Technology, P. R. Kumaramangalam has recently stated that with advanced communication systems the world has been reduced to a global village in terms of its knowledge, its wealth and technology power. Relations between nations are guided more by economic interests rather than security or ideological concerns. In this scenario, its science and technology would determine a country's hegemony in the comity of nations. He has also expressed confidence that the scientific community has both the capability and ability to meet this challenge successfully. The point to ponder, however, is as to how these expectations and aspirations are going to be achieved if science education that has already been quite neglected continues to be neglected!

It is said that we are increasingly moving, and moving faster and faster from an age of things to an age of thoughts, and age of mind over matter. In this new age, it is the mind of man free to invent, free to experiment, free to dream, that is our most precious resource. The value of silicon chip does not lie in the sand from which it comes, but it lies in the microscopic architecture engraved upon it by ingenious human mind. The most promising superconductors are made from ceramics – their value does not come from their material, but from the brilliant inspiration of a few scientists. It is human imagination that is going to build the 21st century out of sand and clay. Let our scientists, science administrators and policy makers ponder whether we will be able to compete with the rest of the nations of the world in the 21st century with the help of policies we had been following during the last 45 years completely neglecting the education of science the way it has been done.

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ACKNOWLEDGEMENTS. I am thankful to Professor P C. Kesavan and Professor Prasanna Mohanty for many useful discussions.

REVIEW ARTICLE

Complex cyclic ketones via oxy-Cope rearrangement – Studies relevant to stereocontrolled synthesis

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Oxy-Cope rearrangement is one of the suitable reactions in organic synthesis that is accompanied by high levels of chirality and regiocontrol. Condensation of β,γ-unsaturated ketones with a vinyl organometallic and subsequent [3,3] sigmatropic shift is the benefit of substantive enhancement in structural complexity with the complementary regeneration of the carbonyl group in a new structural context of polycyclic frameworks. As the carbonyl functionality in synthetic transformations plays a pivotal role, reacquisition of such a reaction site translates into heightened chemical versatility. The trajectories followed by vinyl organometallics as they engage in 1,2 addition to ketones are being understood. Diastereoselective control of this bond-making process when coupled with the chair or boat conformation adopted during the oxy-Cope process is discussed. The synthesis of stereocontrolled elaborate carbocyclics and other complex molecules via oxy-Cope rearrangement, and the developments in the area of oxy-Cope rearrangement and its application to the elaboration of cyclic and polycyclic ketones are compiled in the present paper.