THE INSTITUTION OF ELECTRONICS AND TELECOMMUNICATION ENGINEERS

FIFTH C.V. RAMAN MEMORIAL LECTURE

ON

"POLICIES FOR ADVANCEMENT OF SCIENCE AND TECHNOLOGY"

BY

Prof. P. V. INDIRESAN

28th February 2001
THE C.V. RAMAN MEMORIAL LECTURE
POLICIES FOR ADVANCEMENT OF SCIENCE AND TECHNOLOGY

Professor C.V. Raman was strongly critical of the government for diverting scarce resources from universities to government research laboratories. He felt that the separation of teaching from research will harm both.

These days science education is in the doldrums, engineering studies are little better because most youngsters opt for training in dotcom and Internet. There is a need to refurbish university education so that we can once more produce great scientists like Raman.

Two specific reforms have been proposed to remedy the situation. The first one advocates making all R&D laboratories into Deemed Universities so that the talent and facilities available therein will be available for teaching bright students. The second reform concerns entrance examinations. These examinations have become outmoded. They emphasise rote learning and do not any more bring out creative talent. With barely one out of 50 or 100 applicants being selected, they have also become quite speculative. As an alternative, on the lines of multi-stage filters, it is proposed that students be selected in several stages starting from the primary school level itself for further study in well-endowed prestigious institutions. In that case, at each stage, one-in-three will be selected with lateral entry at each stage. That will make it possible to test the candidates in depth and minimise the chances of not selecting bright students.
FIFTH C.V. RAMAN MEMORIAL LECTURE
"POLICIES FOR ADVANCEMENT OF SCIENCE AND TECHNOLOGY"

1. Sir C.V. Raman As I Knew Him

To see him was to be overawed. Sir C.V. Raman was tall and hefty and oozed self-confidence from every pore of his body. He never stood still. He was enthusiastic and his enthusiasm was infectious. Hearing him lecture was ever an unforgettable experience. I heard him first when I was only fifteen. He bowled us over—even though we did not understand a word of what he was talking about! The next time my encounter with him was psychological, not physical. In my first day as an Honours student in the Presidency College, Madras, our professor reminded us that perhaps we were sitting in the same seat C.V. Raman sat when he himself was a student. That sense of awe never left us all the time we were students there.

My first year at the Indian Institute of Science was also to be the last one for Sir C.V. Raman to be professor there. We used to see him walking around (strutting around would be a more apt word because there was nothing sedate about him). I still have a vivid memory of the way he chased out the cameramen of the Documentary Films of India who had come to make a film on the Indian Institute of Science and, quite naturally, wanted to feature him. He shouted at them with words to the effect: "Your government is asinine and knows nothing about the promotion of science. Don't think taking a picture of me will do anything good to science and don't waste my time! Get out!" At that time, I did not quite understand why he was angry. It took some years for me to appreciate what he was talking about.
2. **Raman's Objections to R&D Laboratories**

Raman was furious because, around that time, on the model of the National Physical Laboratory at Eddington in England, the government established the NPL in Delhi. Raman's argument was that the money should have gone to a university institution, naturally his own! Setting aside his personal pique, there was much justification for his annoyance. For a start, it is no accident that virtually all Nobel Prizes have gone to universities and few to far better endowed non-academic research laboratories. The reason is simple: good research needs young research students. Hence, diverting talented researchers from academic institutions to full time research hurts both ways: Full- time researchers lose the stimulation that only young research students can give. Students too lose because the best minds are drawn away from teaching. In particular, applied research is liable to be siphoned away completely from universities. At the same time, without the discipline of teaching, researchers are liable to lose touch with basic principles and the quality of their research is liable to suffer. So, isolation of teaching from pure research (at times, even applied research) will hurt both research and teaching.

All these fears of Raman have come true. Pre-independence India produced stalwarts like Raman, S.N. Bose, J.C. Bose, Meghnath Saha, H.J. Bhabha, Birbal Sahni and others. After Independence, such flow of talent has dried out in spite of massive increases in government funding. Primarily that is because of the diversion of both physical and human resources from universities. As a consequence, the quality of teaching too has come down. As a matter of poetic justice that has hurt the laboratories themselves - the scientists they recruit are less well educated than they could have been.

3. **Sad State of Science Education in the Country**

Today, fifty years Independence, everyone admits that science education in the country is in the doldrums. The days are gone when bright youngsters fought for admission to science courses. Only when they fail to secure admission to engineering, Medicine,
commerce and every possible teaching shop for computer courses, do the thoughts of modern youth turn to science. That is a pity because without good science as a base there can be no good engineering or medicine. Engineering studies too are not in a good shape because irrespective of the branch that the engineering students study, they are all crazy about dotcom and internet. Whatever discipline they may join, students these days take the first opportunity to convert themselves into computer engineers- more accurately into computer technicians. This state of affairs is not helping the computer industry either because, the way they are trained, most students are fit only for, what Mr. Vittal calls, techno-coolie jobs. It is a matter of grave doubt whether such persons will be able to take on international competition in this fast changing, fast globalising world.

Bright youngsters need role models and that is what they lack most in India. When Raman retired, Professor R.S. Krishnan (among whose claims to fame includes the fact that he was Sri T.N. Seshan's father-in-law), never sat in the chair used by his Guru. That was "Professor's Chair", meant for the "Professor" and none else. That was the veneration that he gave to Sir C. V. Raman. When Professor Krishnan moved out, the room occupied by Sir C.V. Raman was handed over to the Accounts Officer and it is possible that the chair Raman adorned has become the property of some lower division clerk. That is our sense of history. That is the respect we have for the greatest Indian scientist of the Twentieth Century. Then, why should it come as a surprise that today's youth have little or no respect for science and prefer to become accountants?

The state of engineering education is little better even though the demand for engineering education is enormous and there are now over 800 colleges claiming to teach the subject. In truth, most of them are teaching shops that give some sort of training and next to no education. Quantity is no substitute for quality.

Over the years, we have distorted education to a process of learning-by-heart "typical questions and model answers". The system of Entrance Examinations starts that epidemic even before
a student is admitted. Entrance examinations were first introduced by the IITs partly to cope with the flood of applications, partly because the integrity of high school examinations came under a cloud and mostly to protect themselves from political interference. At any rate, it was merely a tool. Now, what was once a tool has now become deity!

4. Bane of Entrance Examinations

There is a proposal to have one single nationwide entrance test to decide the admission to every single engineering college in the country. The incongruity of forcing a single straitjacket on to every kind of engineering institution in this era of decentralisation appears to be lost on our policy makers. The problem with entrance examinations is that it breeds a class of students who can only prepare themselves to answer known questions and not solve unknown, unexpected ones. When C.V. Raman was sailing in the Red Sea on his way to England, he noticed the sea was blue. He asked himself the question, why was the sea blue. Millions of people had sailed before him and had never the curiosity to raise that question. Even if they had, they did not know how to answer the riddle. Raman could do both and therefore won the Noble Prize. Can our education system arouse that sense of curiosity in our youth and train them to solve such basic questions?

Even at the mundane level of physical management, a universal entrance examination is an anachronism. Imagine what a disaster it will be if the question paper leaks out in some corner of the country. We will have to re-examine a million students all over again just because there was one crook in some obscure town. There is yet another mechanical problem. The range of marks between the highest and the qualifying level will be about 50 in any one subject. Then, the maximum range for the three papers of mathematics, Physics and Chemistry taken together will be 150 marks. Within this range, the Entrance Examination will have to list in the order of merit over a 1,00,000 students on an average, there will be nearly 700 students for any given aggregate mark, often that could be as many as 2000. For that
reason, the system offers next to no discrimination for the purpose intended.

The intellectual limitation of the Common Entrance Test is even more serious because a single examination assumes that there is only one type of engineering and only one type of candidate can be a successful engineer. It certainly offers no scope for the likes of Einstein who failed in high school mathematics. It looks as though the Entrance Examination is collapsing by the weight of its own success. In moderate doses, entrance tests are undoubtedly useful. Taken to absurd extremes it becomes unviable both academically and administratively.

Then, there are three fundamental issues that are vitiating education in science and technology in the country. One is the reluctance of bright youth to take up science as a career and the complementary stampede into engineering courses. There is too little of one and too much of the other. The second is the diversion of resources from universities to narrowly specialised research laboratories. Compounding these two problems is the siphoning of talent away from the teaching profession. It may sound as a hyperbole to say that the country's future prosperity depends on resolving these issues. Yet, such an assertion will not be far from truth. The remedy lies in fulfilling the needs of genuine scientists.

5. **Maslow Needs**

**Physical Needs**: According to the psychologist Maslow, human needs are basically five in number and they appear in a sequential hierarchy. At the lowest level are Physical Needs. They will be satisfied only where there is adequate income. On that score, students can be attracted to science by raising the salaries of scientists. However, those that are attracted only by money are unlikely to become great scientists. Let us not forget that Raman took a substantial cut in income to shift from employment in the civil service to become the Palit Professor of Physics in Calcutta University. That is the spirit that creates great scientists.
Even otherwise, a professor in an Indian university earns twenty times the national per capita income; in the US, professor's salaries are generally barely three-four times the per capita income. Hence, in relation to the nation's capacity to pay, university professors are already generously paid. Thus, both from a physical and a psychological point of view, raising salaries is not a suitable solution.

**Security Needs**: Security Need is at the next higher Maslow level. University professors are already more than secure. In Western countries, the slogan is "publish or perish". In India, no matter how badly a teacher performs, there is always a promotion round the corner - by becoming sufficiently senile. So, increased security too is not the best way of attracting scientific talent.

**Status Needs**: Status Need is at the third Maslow level. Traditionally, the status of teachers and scholars used to be high in India, often higher than even that of the rulers. That is no longer the case. Nowadays, clerks in the administration push them around, and therefore, enjoy de facto a higher status. On the other hand, that kind of humiliating treatment is the bane of everybody. Systematic destruction of self-respect of all persons, high or low, has become a notable feature of Indian democracy. S officers are subjected to untold humiliations all the time. Even cabinet ministers are often treated like domestic servants by their "supreme" leaders. In an environment where only power and money count, it is little wonder that professional expertise commands next to no respect. Scientists who have migrated abroad generally cite the absence of a scientific culture as the greatest deterrent to their return to their homeland. Absence of respect for scientific pursuits is another way of expressing that state of affairs.

Thus, giving teachers and scientists the respect that is due to them, the kind of respect they get as a matter of routine in developed countries, will remove one disincentive that discourages youth to pursue teaching and research careers. In general, raising the status of teachers and researchers needs no extra money; better manners will suffice. However, national
and international travel to meet their counterparts is an age-old tradition among scholars and an essential status need. In India, at least for teachers travel facilities are poor and the procedures are humiliating in the extreme.

It is often said that the National Science Foundation of the United States will ask a proposal to be resubmitted if it does not include sufficient amount for travel. The Foundation takes the view that a study worth doing is worth disseminating widely. In India, there is no such sensitivity. The official view is attending seminars is a waste of time and money. Until this primitive notion is changed, and researchers attending seminars is treated as a matter of national prestige, ambitious youth will not be attracted to Indian science. Incidentally, such travel costs little. Indian universities have at the most a couple of thousand active researchers. A budget no larger than Rs.30-50 crores a year will suffice to meet this Status Need for all of them.

**Autonomy Needs**: Autonomy Needs come next. Here a lot more needs to be done, even more than in the case of Status Needs. A university is expected to have three freedoms: the freedoms to decide whom to teach, who will teach and what to teach. Precisely on these counts, government interference is greatest. Sir Ashutosh Mukherji could invite a Raman who had no teaching experience whatever to occupy the most prestigious chair in science in Calcutta University Can any vice-chancellor dare do such a thing now? Imagine insisting that Bismilla Khan should take as shishyas only those who pass a common entrance test conducted by the government! But that is exactly what the government wants and to which intellectuals meekly acquiesce.

Modifying syllabi in our universities involves archaic and tortuous procedures and subject to "democratic" rather than intellectual control. Scholarship is not the adoption of the average but the pursuit of the exceptional. Only those who are iconoclasts, who challenge authority and strike out on a new path of their own, become great scholars. Without such intellectual autonomy no university will become great. Great research needs questioning minds. Such minds will not flourish in a servile or stultifying
atmosphere. That is why higher education is elitist and neither puerile democracy nor autocracy can build great universities, and certainly that is not the way to attract and nurture great minds. No doubt, such minds need royal patronage but they cannot survive under royal tutelage.

**Self-actualisation Needs:** Finally comes Self-actualisation Needs - the need to pursue whatever activity a person wants to excel in. There is hardly any one in the country who can honestly say that the country offers the opportunity, the freedom, let alone the encouragement to excel. The government is deeply concerned about the weak and the disadvantaged and rightly so. In that zeal, the government has thought it fit to handicap the competent, to discourage the brilliant and confine patronage to the incapable. No doubt the government makes much of a Kalam here or a Swaminathan there who manages to survive in an environment of total hostility to competence. That will not suffice where the infant mortality among talented youth is virtually hundred percent.

Sadly, great minds are few. Of the millions who graduate from schools every year, barely a few thousand have the intellectual potential, the internal fire and motivation and the spiritual strength to pursue R&D as a career. It is fair and proper for the government to patronise the poor and the under-privileged. At the same time, it would be wise to set apart a small niche for those who are exceptionally well endowed intellectually. Just as the poor have their rights, the competent too deserve to have rights of their own, particularly the right to pursue knowledge at a pace faster than others and to mingle freely with like minds.

There is a well-known fable in which a jealous person obtained a boon on condition that his neighbour will get twice as much. So, he prayed that he might lose one eye so that the neighbour will lose both of his. Many of our politicians operate on that principle. They would rather impoverish their vote banks than let others prosper. No nation can prosper that ties down talent to the pace of the under-endowed. or let them flee to other countries the way we do.
6. A Search for Solutions

Success in any field, including science and technology requires innate talent, the specific talent matched to the requirements of each case. Obviously, with the best will in the world, one cannot make Lata Mangeshkar a tennis champion nor Tendulkar into a Tagore nor teach Arundhati Roy elementary arithmetic.

So many outstanding minds have emanated from poorly endowed families that it is certain that talent is not confined to the privileged classes alone. Dr. Kalam is one such example. He started in life with every possible handicap imaginable. Though not illiterate, his parents were unschooled and poor. They belonged to a community of artisans that did not set much store on bookish learning and on any type of formal education. They also lived in a remote corner of the country with next to no educational facilities. At the same time, Dr. Kalam did enjoy several advantages.

a. He was intelligent with mathematical skills far above his peers.

b. Though not educated, his parents were wise and inculcated in him high cultural values.

c. His family was willing even to pawn jewels to support his education.

d. He had a teacher who recognised his talents at a tender age, and went out of his way to encourage him and persuaded his parents to sacrifice their short-term profit to let him study in the middle school.

e. He had in him a desire to excel, to succeed.

f. He had the opportunity to work in ISRO where the work was of the highest quality and where everyone was driven to excel and succeed.

These advantages outweighed his handicaps. Similar factors will be found to be the case with many others who achieved great success in life in spite of emanating from disadvantaged backgrounds. Most of these advantages are internal, and the state
can do little to help. Yet, it can, as a matter of policy adopt the following:

a. Encourage mass media to promote high quality family-values and active interest in educating children.
b. Provide good quality nutrition to mothers and children.
c. Make school education affordable.
d. Provide, as Dr. S. Radhakrishnan suggested in his Education Commission Report, compensation to poor parents for the pecuniary loss they suffer when they send their children to the elementary school instead of having them perform full-time domestic chores.

None of these suggestions, except the one for compensating parents of school going children, involve additional financial outlay.* However, the cost should be within the means of the central or state governments.

Politicians will object to selecting teachers on merit and prefer to use those appointments for political patronage. Which would help the poor children more - a Shivasubramnia lyer or someone selected on the basis of caste and patronage?

The main thrust of the argument here is that the government should take particular care of talented youth. Then, the government would do well to adopt the following policy.

a. Identify talent in a tender age (That is the main reason for the phenomenal success of the Chinese in all endeavors)
b. Nurture selected talented children from a tender age by providing the means to cultivate that talent.
c. Provide a competitive environment to help such talented people hone each other’s skills to the sharpest possible level of brilliance.

* One adult family member may be given paid work each day the child attends school and provided the total attendance is no less
than 90 percent. The daily wage may be kept at, say, two-thirds of the minimum wage, the reminder treated as the fee for education. At Rs. 60 per day and for 150 days in the year, that will come to about Rs. 10,000 per year per child. About 20 million children in primary schools may demand this facility. So, the total cost of this scheme will be of the order of Rs. 20,000 crores per year.

d. Select the best available teachers, the best intellectually, emotionally and culturally. (Teachers have to be the best because they are the intellectual seed of the next generation.)

Indian politicians are likely to object to the last suggestion as they normally wish to use teachers' selection for political patronage. Such politicians will do well to consider "Which will help the poor more - teachers like Sri Shivasubramanya lyer or the kind that the government appoints on political grounds?"

7. Identifying and Nurturing Talent

The man thrust of the argument here is talented children should be identified at a tender age and accorded a challenging and stimulating environment. Usually centrally organised written examination are used to select students for special treatment. Written tests with secret question papers, and open for all, have several disadvantages. They cannot match the large variety of backgrounds the children come from. They do not inspire much confidence. However well the questions are designed, somebody or the other will complain that they were either too difficult or out of syllabus or inappropriate. Physical management, distribution of question papers, collecting answer books, valuing them, and maintaining secrecy are all difficult, if not impossible. Above all, secrecy is threatening. As communication engineers, we all know that the characteristics of multi-stage filters will be superior to any single stage on. Hence, entrance to an IIT or any other prestigious institution is best organised in several stages as below:

a. All selection examinations will have open questions disclosed beforehand and set at a level only talented minds can answer.

b. Students own teachers will conduct a preliminary test and
shortlist a number depending on the numbers that qualified in earlier years.

c. The tests will be held at four stages - at the end of the primary, the middle, the secondary and the higher secondary levels for admission to select prestigious Institutions at the next level.

d. In order to help late developers, lateral entry will be made available at each level.

e. The admitting institution will test the knowledge of the shortlisted candidates in depth and not in breadth - in the field of their own choice, as in the case of the Mastermind quiz on the BBC.

f. Each admitting institution will admit students only out of the shortlist, which will be no more than two-three times the numbers admitted.

This system empowers those who have taught the children to make the shortlist, it ensures they select the best because, if they play favourites, the number they can shortlist in the future is liable to get reduced. At the preliminary selection level, questions are open; so the tension is minimum. At the final selection stage, questions are both open and open-ended but the tension is still low because the candidates themselves choose the area where they like to be tested. That will separate those who think from those who mug up.

The administrative and financial burdens will be very low under this scheme. As the examinations are highly decentralised, students from backward regions have as good a chance as those from cities. Multi-stage selection ensures that the numbers taper off gradually and not abruptly as in the current system of one-shot entrance examinations. Lateral entry offers extra opportunities for those who miss out at any stage for any reason whatever.
8. Empowering the R & D Laboratories and Academic Institutions

Raman’s concern, that full-time research laboratories will not be as fruitful in the advancement of basic principles as academic ones, remains to be addressed. As matters stand, it is not possible to transfer either the human or the physical resource from R & D establishments back to the universities. However, there is no major obstacle for each of these laboratories to become a Deemed University and take to teaching in addition to their normal R & D tasks. Such Deemed Universities may stimulate bright students even better than conventional ones.

One further reform is needed to empower these institutions. Status is very important for teachers and researchers. They cannot have a high status unless the institutions in which they work are prestigious. Those institutions will have prestige only when they are autonomous and free from political and other outside interference and control. The IITs are as good as they are mainly because they enjoy considerable autonomy. We need to institutionalise such and even more autonomy for all educational and research institutions.

For that purpose, we may consider installing two autonomous boards for each institution. One will be the Board of Trustees composed of those who provide the capital. They oversee the future development of the institution, operate the capital budget, and will also select the CEO, COO and the CFO of the Institution. A second body, the Board of Governors will be composed of reputed academics headed by the CEO and assisted by the COO and the CFO. This board will have autonomous jurisdiction over academic and research affairs and operate the recurring budget. Such an arrangement has worked well else where. It is the best way of satisfying the autonomy needs of the academic and research staff without the fund providers losing management control.

9. Conclusion

How can we identify and nurture talents like those of Sir C.V. Raman, and do so however poor their background may be? That is the query I have tried to answer in this talk. In brief, I expect that the quality of both Indian teaching and R&D can be expected to rise to international levels if:
a. Talented children are identified at the primary school stage itself and however poor, they are all empowered to get high quality education.

b. Lateral entry at higher levels is introduced to help late developers.

c. Admission to prestigious colleges is done through a multi-stage, two-step process with shortlisting done by those who taught the children and the final selection by the admitting institution.

d. R&D laboratories are made Deemed Universities to offer additional high quality academic opportunities for bright students.

e. All academic and R&D institutions enjoy full academic freedom, and administrative autonomy too, in day-to-day affairs.

Admission rate in centrally conducted entrance examination can be as little as one in fifty or even one in hundred. That way many talented students are liable to get wrongly rejected. In the proposed system, at each stage, around one in two or three is selected. That minimises the probability of any talented candidate being rejected.

This system fulfils Maslow Needs quite well - but in reverse order. The multistage selection ensures that students do not make random choice but self-actualise by repeatedly opting for the course they like best. Letting candidates select the area of final test satisfies their Autonomy Needs. Admission to prestigious institutions will satisfy Status Needs. That guarantees a secure future - and fairly substantial incomes too.

Will these steps ensure that bright students will not forsake science and technology for more remunerative careers like selling soap? They may not succeed every time but those who have spent years under motivated teachers are likely to choose as Sir C.V. Raman did - prefer academic challenge over power and money.

Let me hope that the ideas I have suggested here will find favour with policy makers and that we will start producing Nobel Prize winners in abundance in the near future.
a. Talented children are identified at the primary school stage itself and however poor, they are all empowered to get high quality education.

b. Lateral entry at higher levels is introduced to help late developers.

c. Admission to prestigious colleges is done through a multi-stage, two-step process with shortlisting done by those who taught the children and the final selection by the admitting institution.

d. R&D laboratories are made Deemed Universities to offer additional high quality academic opportunities for bright students.

e. All academic and R&D institutions enjoy full academic freedom, and administrative autonomy too, in day-to-day affairs.

Admission rate in centrally conducted entrance examination can be as little as one in fifty or even one in hundred. That way many talented students are liable to get wrongly rejected. In the proposed system, at each stage, around one in two or three is selected. That minimises the probability of any talented candidate being rejected.

This system fulfils Maslow Needs quite well - but in reverse order. The multistage selection ensures that students do not make random choice but self-actualise by repeatedly opting for the course they like best. Letting candidates select the area of final test satisfies their Autonomy Needs. Admission to prestigious institutions will satisfy Status Needs. That guarantees a secure future - and fairly substantial incomes too.

Will these steps ensure that bright students will not forsake science and technology for more remunerative careers like selling soap? They may not succeed every time but those who have spent years under motivated teachers are likely to choose as Sir C.V. Raman did - prefer academic challenge over power and money.

Let me hope that the ideas I have suggested here will find favour with policy makers and that we will start producing Nobel Prize winners in abundance in the near future.
Proposed Multi-stage Talent Search

Cohort size at primary level 10-15 million
Shortlist - 6 million

Admission to Class VI - 3 million
Shortlist - 1 million

Admission to Class IX - 500,000
Shortlist 200,000

Admission to Class XI - 100,000
Shortlist 50,000

Admission to University 15,000