Scientific research, technological development and innovation are key factors in the growth and development of a nation. Over the years, there have been serious concerns raised about basic sciences being unable to attract bright young students. The falling standards of university education and the miniscule contributions they make to research and development are areas that require immediate attention.

The National Conference on India's Competitiveness and Preparedness in Science and Technology During the Coming Decades: Issues, Challenges and Strategies organized by National Institute of Advanced Studies Bangalore and Jawaharlal Nehru Centre For Advanced Scientific Research, Bangalore, focused on critical areas that require a wider debate in the context of international competitiveness. In addition to ways of attracting and retaining persons in the disciplines, attention to institution building linked to building capacities to engage in frontier areas of research were also addressed.

It was an attempt for the first time perhaps to bring to a common platform, younger scientists with their senior counterparts along with women scientists representing universities, research institutions and the industry to discuss this important issue. Given the wide range of participation from all stakeholders, the report contains key issues that were raised in the presentations and discussions during the two days proceedings. The report will be of interest to all those who are concerned with the growth and development of science and technology in the country and in the world.

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India's Competitiveness and Preparedness in Science & Technology

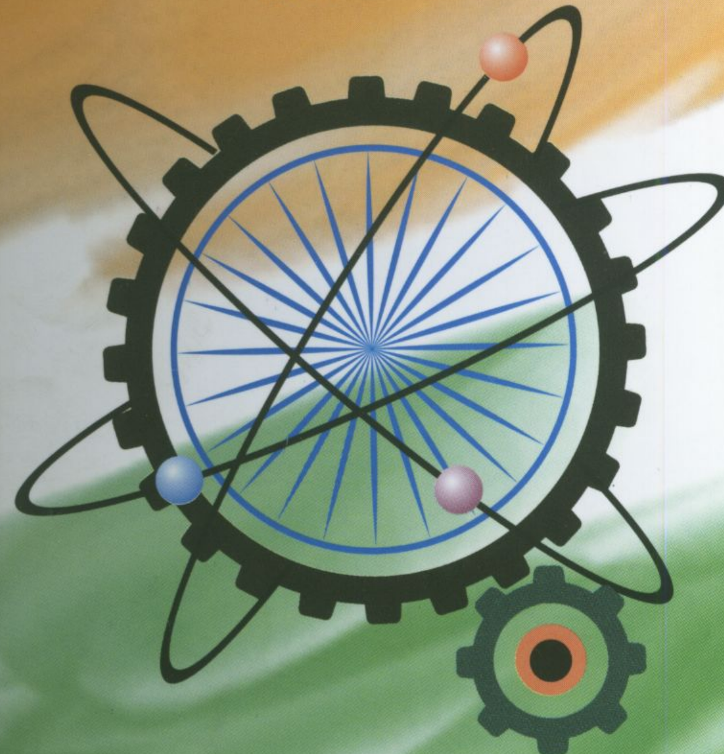
B. K. Anitha

NIAS & JNCASR

National Conference on

India's Competitiveness and Preparedness in Science & Technology for the Coming Decades Issues, Challenges and Strategies

B. K. Anitha



Organized by

National Institute of Advanced Studies
Bangalore

Jawaharlal Nehru Centre for Advanced Scientific Research
Bangalore

National Conference on India's Competitiveness and Preparedness

In

Science & Technology for the Coming Decades Issues, Challenges and Strategies

By

B. K. Anitha

Organized by

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Bangalore

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Bangalore

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Foreword

Scientific research, technological development and innovation are key factors in the growth and development of a nation. Over the years, there have been serious concerns raised about the ability of the basic sciences to attract bright young students. The falling standards of university education and the miniscule contributions they make to research and development are areas that requires immediate attention.

In addition, the processes of globalisation, liberalisation and privatization have lent a complex dimension to the expansion of education, the degree of professionalization, and the nature of employment. The growth of career opportunities in the emerging fields like the IT, biotechnology, management and law, where specialization is at the graduate level, have seriously hampered the recruitment and retention of students and scholars in the fields of basic disciplines like mathematics, physics and chemistry.

Given the range of problems besetting the development of S&T in the nation, it is important to take stock of the situation and develop strategies to address them. The National Conference on India's Competitiveness and Preparedness in Science and Technology During the Coming Decades – Issues, Challenges and Strategies was an attempt in that direction.

This National Conference was the brainchild of Prof. C. N. R. Rao. Under his mentorship, we were able to conceptualise and design the conference to facilitate a meaningful deliberation on this very important issue. I also acknowledge with appreciation my colleagues Prof. Sundar Sarukkai and Dr. B. K. Anitha who have significantly contributed to this conference. It was jointly organised by The National Institute Of Advanced Studies, Bangalore and the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore at the JRD Tata Auditorium, National Institute of Advanced Studies, Bangalore. This was probably the first forum bringing together all stakeholders in S &T including Science & Technology Institutes, Government Laboratories, Universities and Private Industries. It was an attempt for the first time perhaps to bring to a common platform younger scientists with their senior counterparts along with women scientist to discuss this important issue.

This conference focussed on critical areas that require a wider debate in the context of international competitiveness. Institution-building and other ways of building capacities to better engage in frontier areas of research were raised and discussed in addition to ways of attracting and retaining persons in these disciplines. It was clear that contemporary and future S&T regimes and practices need to take into consideration the broader dimensions of multi-disciplinarity, inter-institutional and transnational collaborations at all stages of research. Given the wide scale participation from all stakeholders, the report contains key issues that were raised in the presentations and discussions during the two days proceedings. The report will be of interest to all those who are concerned with the growth and development of science and technology in the country and in the world.

K. Kasturirangan
Director, NIAS

Acknowledgements

We are happy to acknowledge with thanks the opportunity given to us to organise this National Conference on India's Competitiveness and Preparedness in science and Technology during the coming decades. The planning and conceptualisation of the conference in particular benefited largely through the several rounds of detailed discussions we had both at NIAS and JNCASR. We place on record our deep sense of appreciation to the following organisations and individuals who contributed to the conference in various ways.

The conceptualisation and planning of the conference was done by Prof C. N. R. Rao, Linus Pauling Research Professor and Honorary President, JNCASR; Dr. K. Kasturirangan, Director, NIAS, Dr. Sundar Sarukkai and Dr. B. K. Anitha.

Additional Inputs were given by Dr. Carol Upadhaya, Dr A. R. Vasavi and Mr. Nithin Nagaraj.

The conference would not have been possible without the meticulous and able secretarial and administrative support given Mr A. Deva Raju who really took off the load of organising the conference and released our time to concentrate on the proceedings and discussions in the conference.

We have and continue to depend on Mr. C. Shashidharan for the technical support, which he does with a great sense of competence and efficiency.

Mr. Kumar who patiently completed the visual documentation.

Ms. Dhanwanti Nayak, for her excellent job done in relation to transcription and reporting that made the preparation of this report relatively easy.

This conference was possible with the liberal financial support of the Department of Science and Technology, Government of India and we are thankful to them.

Paper presenters, chairpersons and the participants whose discussions is the outcome of this report.

Executive Summary

The National Conference on India's Competitiveness and Preparedness in Science & Technology for the Coming Decades: Issues, Challenges and Strategies organised by National Institute of Advanced Studies (NIAS) and Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) was probably the first forum bringing together all stakeholders in S &T including Science & Technology Institutes, Government Laboratories, Universities and Private Industries. It was an attempt for the first time perhaps to bring to a common platform younger scientists with their senior counterparts along with women scientist to discuss this important issue.

The conference opened on a right note with, Shri Kapil Sibal, Union Minister for S&T, GOI, calling attention to the fact if the scientific community in India are an endangered species? A clear articulation of a vision and a roadmap is the need of the hour. The keynote address of C. N. R. Rao recalled that meetings of this kind were organised earlier but the last one held was in 1985. He drew attention to the fact that if India needs to be competitive in science, an honest inward looking and an urgency to take harsh measures rather than invoke incremental changes in policy, administration and institutions if India as a country, (and not as individuals) has to be on the radar of world science today.

The conference was organised into 5 panels:

1. Is Indian Science Competitive?
2. Science in the World and in India: Some Experiences;
3. Science and Technology Institutions;
4. Collaborations and Partnerships; and
5. Science as a Career.

Its charter was to take stock of the current situation by taking into cognisance the findings of the recent reports[1] and develop strategies to enhance India's competitiveness in S & T.

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[1] Inventing a better Future – A Strategy for Building Worldwide Capacities in Science and technology, IAC, (2003); Task Force to study the status of Basic Scientific Research in Universities under the chairmanship of Prof. M.M Sharma submitted to GOI in 2005

The summary of the presentations and discussions are presented below. They have been organised around the following four major categories:

- Human Resources
- Grants and Funding
- Institutionalisation
- Administrative and Work Environment Facilitators

Panel 1 Is Indian Science Competitive?

Summary of Current Situation

If we need to be globally competitive, there are several issues which must be addressed. The dearth of good quality institutions and teachers for undergraduate and graduate education in the sciences across the country; the decline in number of quality students that science can attract and institutions can produce; the lack of institutionalisation of processes and the personalised functioning of leadership in keeping with the larger culture which prefers concurrence over dissent, conformists over critics; the restriction of science institutions to the same geographical areas, with an additional emphasis on urban centres, leaving a large part of the population out of their gambit.

Recommendations

Human resources

- Increase the HR pool by strengthening college and university systems across the country by restructuring and infusing them with funds. Teaching laboratories, in particular, should be modernized and well equipped.
- Initiate an undergraduate and Master's teaching programme in all research institutes which are open to local college and university students so that students get exposure to the best of researchers and the working environment of science early on in their education.

Grants and Funding

- Develop India as an education and employment destination in S&T research and higher education. Funds must be made available for publicizing Indian research and teaching institutions abroad.
- Retain Indian scientists in India with a combination of salary, incentives and excellent work conditions. Target scientists from across the world for employment in India.
- Fund alternative technologies strategically to lower our dependence on scarce and depleting resources.

Institutionalisation

- Enforce transparency in processes, uniformity of rules, and consistency in application of the same in institutions and universities with immediate effect under the Right to Information Act.
- Establish a Science Observatory to study, evaluate and monitor science and scientific institutions in India and the world. Performance indicators such as citation index and impact factor citation analysis may be used and resources must be simultaneously invested to develop newer and more equitable indices based on developments in modern scientometrics.
- Promote the adoption of Open Access Archiving at all scientific institutions to create a virtual knowledge environment which is accessible to all.

Administrative and Work Environment Facilitators

- Develop a vision/mission plan for a time-defined future with different roles for all stakeholders, and a differentiated funding programme involving investments from public and private players for "thrust" areas. Ownership of this vision/mission plan for S&T must be at the highest levels of the Government. All stakeholders must be involved in its development and consensus building must be accorded top priority in developing it.
- Promote competitive market conditions to ensure a component of need-based/applied science and technology.

- Give incentives and tax breaks for private investments in R&D.
- Develop an aggressive, efficient and proactive International Patenting/Intellectual Property system.
- Institute mechanisms to sustain initiatives under changing political and economic cycles.

Panel 2 Science in the World and in India

Summary of Current Situation

The strengths of post Independence Indian S&T are getting eroded. There is a concern that countries like Japan and China have pulled ahead of us in a very short period of time due to dynamic policy changes, massive infusion of funds and the strategic use of networks and collaborations. On the other hand, we continue to loose many fully trained and potentially good researchers to the West without being able to produce as many as the country needs in short periods of time.

Recommendations

Human Resources

- Actively encourage the recruitment of postdoctoral fellows who are a vital component of research groups as well as the general intellectual community for researchers. Make such changes in funding policy as needed to reflect this necessity so that project money may be allocated for their recruitment.
- Encourage the formation of small-group networks through providing financial and other support for regular meetings and establish forums for discussion and exchange of ideas.
- Introduce tenure track systems for faculty positions in research institutes.
- Involve younger faculty as well as women and other disenfranchised groups in every facet of institutional building and science policy making in order to create a sense of ownership and thereby increase morale among them.

Grants and Funding

- Form an autonomous agency comprised of scientists of different backgrounds and ages to make funding decisions.
- Identify thrust areas such as bio-tech, or pharma or alternative sources of energy and support these with adequate resources at all levels.
- Enhance visibility of Indian S&T by proactive financial support for travel to international conferences and publications in international journals.
- Nurture originality among researchers at the beginning of their careers by giving complete and liberal funding of ideas with freedom for a clear length of limited time upto 5 years or so.
- Redress or minimize salary differentials between corporate and academic R&D.
- Set up world-class research facilities in India and provide incentives to attract foreign trained scientists to India.
- Increase focussed funding to table-top science to increase tinkering and innovation.
- Encourage innovation and innovative ideas by funding a select number of "risky" ideas.

Institutionalisation

- Plan for focussed faculty recruitment based on research interests, profile of candidates and make selections based on procedure and complete transparency. Evaluations of candidates must be done in writing and provided on request to them.

Administrative and Work Environment Facilitators

- Clearly articulate and communicate with the scientific community the vision of science. Goals (short, medium long term) need to be updated to contemporary needs, such as the emphasis on collaboration between S&T and industry.
- Balance freedom with accountability and institute a system of rewards for excellence in science which is clearly articulated and disseminated.

- Encourage a responsive, responsible and enabling administration based on transparency, consistency and uniformity, and an emphasis on process.
- Constitute research Institutes more along the lines of academies than government organizations.
- Accord Science Policy statements legal status, develop a clear national strategy for their delivery and support them with funds for their realization based on a clear outlay to all stakeholders.
- Facilitate visas for visits to countries as well as for inviting foreign faculty to India.

Panel 3 Science and Technology Institutions

Summary of Current Situation

There is a crisis in the existing university system as government policy since 1947, has been based on support to institutes, laboratories, departments of Atomic Energy, Space, Defence, ICMR, CSIR and the like, and these are the organizations who get the bulk of government funds for research at the cost of the university system which produces the bulk of the post graduates. Thus, we need to revamp and rejuvenate the university system as it is the single existing mechanism we have, to produce large numbers of competent researchers. Younger people also need to be given responsibilities in this restructuring as they lack exposure and experience in institution building. Emphasis must be on sustaining institutions by strategic changes in policy and practice, and funding those new institutions which are able to demonstrate that they will generate synergy with another institution either by location or institutional practice.

Recommendations

Human Resources

- Conduct workshops, summer internships, science days, exhibitions and visits to institutes and laboratories for high school and undergraduate students to expose them to science practices.

- Cultivate networks since lot of innovation comes from such professional networks and scientists working in groups.
- Recruitment of new students, post docs and faculty should be done through rigorous peer evaluation, rather than personal judgements. All evaluations must be put in writing.
- Recruit proactively for faculty positions and efficiently for positions which fall vacant without leaving a large time lag.

Grants and Funding

- Increase the share of academic R&D in total R&D outlay.
- Infuse massive infusion of funds to revamp and rejuvenate the university system.
- Distribute government funds away from the main centres which are already well established.
- Ensure professional review of proposals by those working in the area of specialization with which the project is concerned.
- Establish, communicate and adhere to strict deadlines for conveying decisions on project proposals with written evaluations provided for rejection.
- Fund projects in their entirety so that time planning and research can be done in a systematic manner.
- Liberalise financial norms.
- Allocate resources and funds in a transparent, uniform and accountable manner.

Institutionalisation

- Establish a forum and create a platform for scientists independent of Government to discuss science policy matters and funding allocations by Government, as well as issues which affect the science community as a whole.
- Ensure (young) scientific voices on science policy, and brainstorm well in advance on the components of the policy.
- Institutionalise rules and processes and separate them from the vagaries of changes in directorship and personal equations.
- Establish Institute-university linkages and evolve mechanisms and programmes to engage with each other

such as through the sharing of resources, faculty, students and offering joint programmes.

- Locate specific labs and new institutes on university campuses to develop synergy between them.
- Involve premier institutions of science in undergraduate teaching.

Administrative and Work Environment Facilitators

- Develop a clear strategy to restructure the university system to accompany the infusion of funds.
- Liberalize undergraduate education with subject selection across the prevailing distinctions between arts, science and commerce. There should be continuous syllabus revision and restructuring of courses.
- Enable administrations to be more flexible and simple in routine matters which otherwise get bogged down in unnecessary paperwork.
- Establish new institutions in research and higher education, if any, away from the 7 states which currently hold sway over them.
- Evolve norms of scientific practice through participation of scientists themselves in recruitment and mentoring of new researchers, evaluation of how research is done, policy-making at organisation and national levels.
- Conduct internal reviews and evaluations of all research institutes and organizations, departments and administration; prepare reports and disseminate findings among stakeholders; address grievances in writing.
- Train and sensitise administrative staff to appreciate scientific work and give appropriate support.
- Provide statutory institutional protection of rules and processes so that change of administration does not interrupt work.

Panel 4 Collaborations and Partnerships

Summary of Current Situation

Government has been the major source of funding for S&T research. While this is necessary, we need to recognise that there are benefits to be gained from collaborations such as those between science and industry, and between nations. Such collaborations result in benefits and spinoffs that accrue to the S&T arena itself in terms of establishing strong small-group networks, developing a culture of interdisciplinary work for researchers, the development of cutting-edge technology and products for industry. IT, bio-tech and pharma industries have also shown that there is a huge demand for advanced researchers in S&T. Private industry is also a relatively untapped source of additional funds and employment for S&T researchers with direct benefits for industry and the markets.

Recommendations

Human Resources

- Encourage and facilitate scientists to spawn companies and also technology transfer through instituting programmes and providing incentives.
- Provide attractive opportunities and incentives for scientists to provide consultancy services to the industry. Reduce bureaucratic hurdles preventing scientists from entering into consulting.
- Develop and offer continuing education programmes to industry researchers at top research institutes.
- Increase research fellowships and career opportunities for postdoctoral fellows.
- Encourage internships in the industry through government funded collaborative programmes directed at industry.

Grants and Funding

- Recognize and reward scientists at levels comparable to their peers in the industry.
- Encourage companies to invest in R&D in the universities or institutes. Build partnerships from the explorative stage, rather than allowing industry to license a developed technology.
- Increase our international stature, create cohesive networks in the country and spawn new technology by allocating specific funds for transnational collaborations which allow really big science to be done that cannot be done alone.

- Institute a system of providing matching or percentage grants to industry to encourage collaborations with industry.

Institutionalisation

- Develop specific models to increase interactions between academics and industry at the institutional rather than individual level. These could be technology or knowledge parks on campuses, technology incubator models, entrepreneurial universities or any other type suitable for our environment.
- Establish systems for collaboration and processes for enabling them.
- Develop systematic ways to approach collaborations with industry starting with feasibility studies. Brain-storming is critical to such collaborations and decisions on thrust areas.
- Institute clear guidelines for industry-institution/university and transnational collaborations such as for IPR sharing. There should be modalities to cover collaboration for all scales of industry – large, medium as well as small.

Administrative and Work Environment Facilitators

- Commission a White Paper on industry-science linkages with all stakeholders, take stock of ongoing major collaborations, draw on best practices from all over the world, conceptualise suitable models, subject areas, key institutions and actors to change the landscape intellectually and economically.
- Create forums to initiate and generate dialogue across industry-academic divide.
- Establish network centres for excellence in specific and key research areas such as bio-tech, healthcare.
- Execute specific initiatives which encourage innovation at the interface areas of science and engineering and allow us to build upon our advantages in science and IT.

Panel 5 Science as a Career

Summary of Current Situation

Science has lost its charm as a career choice for young people. Part of this is due to the failure of scientists themselves to promote science as an interesting career accompanied by a rapid acceleration in the attractiveness of other professions such as law and business management as more lucrative careers. In addition to this is the decline and erosion of educational institutions, from schools through R&D institutions, and the failure to recognise the reality and differential needs and status of women in science.

Recommendations

Human Resources

- Proactive recruitment of students and faculty from less represented geographical areas, castes, classes and communities to make urban research and teaching institutes and universities more inclusive than elitist.
- Proactively recruit and retain women scientists, researchers and faculty.
- Institute mentoring programmes for all disenfranchised and/or under-represented groups to provide active support to them in professional environments.
- Institute mentoring programmes for talented rural youth through the Academies.
- De-link jobs from rigid degree requirements to recruit people of talent, and facilitate capacity building on the job through mentoring and continuing education programmes.

Grants and Funding

- Modernize teaching labs in schools and colleges. Emphasize table-top science in schools and colleges.
- Initiate and publicize a school and college level mathematics and science talent programme to identify and nurture scientifically inclined youth.
- Institute summer training programmes for school and college teachers to inspire, update and share best practices in science teaching.

- Fund research on issues and themes connected with women in science.
- Establish and fund separate support networks for women in science and evolve organized mentoring programmes under their aegis.
- Establish a high-powered Commission on Gender and Science, which will work closely with the making of science policy. Such commissions could also investigate cases of sexual discrimination, malpractices in recruitment and the closure of departments and units engaged with research on gender.

Institutionalisation

- Enable women to build careers in science through proactive institutional policies on maternity leave and flexible work time.
- Encourage the establishment of returning to education and continuing education programmes for women as a way to recognize and redress the practical difficulties associated with the higher education of women.
- Provide adequate crèche facilities within a certain radius at all government-funded institutions, independent of the gender composition of employees, hierarchy and numbers of employees who would be using them. Facilities of this kind may be provided as a perquisite and it's building and running costs calculated as part of institutional infrastructure.
- Conduct gender sensitisation programmes, conferences and workshops for researchers as part of advocacy programmes and orientation sessions to highlight the complexities of professional women and share results of research on women in science.

Administrative and Work Environment Facilitators

- Develop a new policy statement on school education which shifts the emphasis of education – syllabi, teaching and evaluation – from "teaching" to "learning", from information acquisition to learning processes, from memorizing to questioning, from repetition to analysis and creative thinking. Encourage all related government

departments such as NCERT to follow these policy changes.

- Develop a concrete policy delineating the relative importance to be given to basic and applied sciences with proportionate funding allocations through the system. Thrust areas for a given time period (say 5 years) may be identified around a core of basic science.
- Constitute a committee of all stakeholders to bring out, address and understand issues connected with women in science.
- Develop a proactive and supportive policy on women in science as part of the larger science policy of the country.
- Develop gender sensitive textbook material and visuals to address the role of women in science more accurately. For example, through changing their representation in school text books and adding information about women scientists so to bring them in line with their actual professional status.
- Embark on a massive and sophisticated PR programme for changing the image of S&T in the minds of the general public. This should use all media and cover all sections of society throughout the country. The comprehensive strategy could include the commissioning of films and biographies of individuals and institutions, travelling exhibitions, competitions, workshops, students and parent counselling and lecture series in addition to the conventional commercials and advertisements.
- Commission studies on dissensions, dropouts and demoralization among scientists to understand the norms of science.

Action Plan

The executive summary contains the specific suggestions that came up across the board for revamping undergraduate education, university systems, collaborations between institutes, universities and corporates, these can be addressed on a smaller scale with the concerned stakeholders.

The action plan contains those recommendations that came up which can be developed for presentation to the government and may need to be executed at a national level. They are as follows:

Human Resources

- Embark on a massive and **sophisticated PR campaign for changing the image of S&T** in the minds of the general public, so as to attract the best of minds into science as a career choice. The campaign should use all media and cover all sections of society throughout the country. The comprehensive strategy could include the commissioning of films and biographies of individuals and institutions, travelling exhibitions, competitions, workshops, students and parent counselling and lecture series in addition to the conventional commercials and advertisements.
- **Involve younger faculty, as well as women and other disenfranchised groups, in every facet of institutional building and science policy making** in order to create a sense of ownership and retain young scientists in the country. Establish a minimum percentage of young scientists (below 45) who need to be included on every decision making body for S&T, much as has been done for women in university boards and committees.

Grants and Funding

- Form **an autonomous agency to make funding decisions** comprised of scientists of different backgrounds and ages. Projects which are funded must routinely include funds for the recruitment of post-doctoral fellows as well as travel to international conferences to enhance international visibility of Indian science.
- Ensure **professional review of proposals** by those working in the area of specialization with which the project is concerned.
- **Identify thrust areas** such as bio-tech, or pharma or alternative sources of energy and support these with adequate resources at all levels. Increase focussed funding to table-top science to increase tinkering and innovation.
- **Fund research on issues and themes connected with women in science.** Establish and fund separate support networks for women in science and evolve organized mentoring programmes under their aegis.
- **Modernize and equip teaching laboratories in high schools** (standards 9 to 12) as well as undergraduate colleges to generate interest in science.

Institutionalization

- Establish a **Science Observatory** to study, evaluate and monitor science and scientific institutions in India and the world.
- Promote the adoption of **Open Access Archiving** at all scientific institutions to create a virtual knowledge environment which is accessible to all.
- Establish a **Mentoring Programme** through the Academies for talented rural youth and all disenfranchised and/or under-represented groups in institutions to provide active support to them in professional environments.
- Establish **undergraduate teaching programmes** at all government-funded research institutes to offer Bachelor's degrees in S&T. This will enhance the quality of students getting into post-graduate programmes. Limited non-degree programmes, such as weekend courses, summer internships, may also be offered to select undergraduates such as those offered by BASE, Planetarium, Bangalore.
- Institute the equivalent of **Bhatnagar award for undergraduate college teachers** with a minimum of 5 years experience, providing them with additional funds for innovating teaching methods. This will help revitalise undergraduate teaching.
- Establish a **summer training programmes for high school teachers** to inspire, update and share best practices in science teaching in schools.

Administration and Work Environment Facilitators

- Enforce **transparency in processes, uniformity of rules, and consistency in application** of the same under the Right to Information Act in research institutions and universities with immediate effect.
- Develop **a new policy statement on school education** which shifts the emphasis of education – syllabi, teaching and evaluation – from "teaching" to "learning", from information acquisition to learning processes, from memorizing to questioning, from repetition to analysis and creative thinking. Encourage all related government departments such as NCERT to follow these policy changes.

- **Accord Science Policy statements legal status,** develop a clear national strategy for their delivery and support them with funds for their realization based on a clear outlay to all stakeholders.
- **Encourage companies to invest in R&D in the universities or institutes.** Increase incentives for private investments in R&D. Build partnerships from the explorative stage, rather than allowing industry to license a developed technology.
- Develop an aggressive, efficient and **proactive International Patenting / Intellectual Property system.**
- **Encourage research institute-university collaboration** through specific initiatives and mechanisms to engage with each other such as through the sharing of resources, faculty, students and offering joint programmes. Locate research labs on university campuses to develop synergy between them.

Conclusion

Earlier it has been a practise of holding National Conferences on central issues that deal with India's Future in Science and Technology more frequently. The last one held was during the year, 1985. Leading scientists and policy makers in the country discussed and debated several issues related to the central theme during the meetings. This conference after a lapse of 20 years was organised with a specific focus on India's Competitiveness and Preparedness in Science and Technology in the coming decades – Issues Challenges and Strategies.

The conference was successful in more ways than one. It for the first time created a forum for the scientific community to raise issues that represented the concerns of the community at large particularly the younger faculty. The participation of the universities and the research institutions on a common platform was useful to bring to centre-stage the fact, that one is not independent of the other. The conference also placed the question of competitiveness in science and technology is intrinsically related to the culture of excellence and hence not independent of development in related fields of knowledge.

On the other hand, the conference also generated a long list of recommendations, not all of them were new in terms of strategies. However, the issues raised at the conference can be treated as a wider canvass of concerns among the scientific community. The action plan is the articulation of the recommendations raised in a more specific form. A committee from diverse backgrounds can treat the entire document along with action plan as a draft, which needs further thought and action. In that sense, the conference can be seen as an initiative to create a wider network and draw out a long term inter-institutional programme.

Introduction

Globalization, liberalization and privatisation have changed the nature of education, professionalisation and employment in all sectors. In addition, precarious energy and environmental issues bring to the forefront the question of sustainability. Lastly, changing demographic distributions of populations suggests that global and local needs be addressed. The role of science and Technology as a key factor in growth and development of an economy cannot be over emphasised. There is an urgent need to increase India's Competitiveness in S&T through specific initiatives.

Conference Design

The conference drew on representatives of all stakeholders including Science institutes, Laboratories, universities and industry.

The conference was designed to keep the focus of 'India's competitiveness and preparedness in science and technology' as central in all the deliberations. This was done through the organisation of panel discussions with more number of presentations for relatively shorter time of 10-12 minutes per presentation. Since the conference drew on a large number of participants throughout the country with the limited discussion time, not all of them could raise questions. Foreseeing this limitation, the organisers had created working groups for each of the panels from amongst the participants who were then given an opportunity to raise issues that did not figure out either in the presentations or discussion of the panel theme. Presentations by the chair of the each of the working groups were made in the final session of the conference. Hence, the working groups were created to facilitate wider participation particularly of the relatively younger members of the community as well as women scientists.

The central issues discussed in this conference can be broadly categorised as :

- Lack of competitiveness of Indian science.
- inability to attract bright young students to research into basic sciences.
- falling standards of the university system and lack of its contribution to R&D.

- low levels of funding and capacity building for individuals and systems, given shrinking resources and high costs.
- failure to institutionalize.
- necessity to collaborate.
- prioritisation of R&D given challenges from new disciplines and sectors, limited resources and national and international needs.

These problems were addressed under five broad themes discussed in panels.

Panel 1: Is Indian Science Competitive?
Panel 2: Science in the World and in India: Some Experiences
Panel 3: Science and Technology Institutions
Panel 4: Collaborations and Partnerships
Panel 5: Science as a Career and a Plenary Session

Structure of the Report

The report captures the highlights of the key presentations in all the sessions beginning with the introductory session, panel discussions and the plenary session. Important points made by the chair along with those raised during the discussions find a place in this report. The report is in the present tense and unfolds as a part of the two days proceedings.

Introductory Session

Introduction Remarks: Dr K. Kasturirangan, Director, NIAS

This meeting is being held jointly by JNCASR and NIAS. It is the brainchild of Prof CNR Rao to address this issue by inviting all stakeholders. We need to create an environment to make Indian science and technology competitive and this meeting will make sure we see all the issues and come up with a strategy to address them in the coming decades.

The meeting has been structured by Prof CNR Rao as a series of panel discussions on specific themes. There have been a large number of reviews and assessments that have been carried out – Science and science promotion in the Universities by Prof. M.M Sharma, IIT upgradation by Prof. P. Rama Rao, Inter-Academy Panel on Capacity Building in Developing Countries. We thought we would also present the outcomes of this meeting to the minister who was himself interested in HRD, performance criteria in science, institutional restructuring, funding mechanisms, international collaboration and the like.

The appropriateness and timeliness of the conference is critical also in the wake of developments in the country such as liberalization and globalisation, WTO, increasing competitiveness as industry is moving where maximal returns are assured, social well being and sustainable development strategy keeping in mind energy and environment issues.

When we talk of the coming decades what does it imply for India? Demographic patterns show that in 2020 in every 100 dweller, 56 Asians, (19 from china, 17 Indians) 16 Africa (13 Sub Saharan) 7 from new Europe including former USSR 5 Europe, 3 Middle East, 13 from Western Hemisphere including 4 from USA. Therefore, we need a population which can leverage S&T capability for the nation and the whole world. We need to create a sustainable and fertile environment capable of leveraging knowledge-based resources, particularly S&T.

Some of the questions we are trying to address in this conference are,

The place of India with regard to the world in S&T; how competitive is Indian science with regard to the world and how have we fared over the years with reference to ourselves. We also need to see what is the response of the state to prepare the scientific community to face the future challenges.

These challenges are defining problems facing the world in terms of multi-disciplinarity and increased collaboration; framing broad responses to them taking into account the complexity of research, shrinking resources and high costs and the reality that individual

countries cannot do some kinds of research by themselves; mechanisms to set priorities on rational grounds; challenges to balance between different kinds of research - applied and non-applied, basic and applied etc; challenges to progress of S&T needs to cope with explosions in knowledge. Lastly, the linkages of S&T with knowledge, society, economy, research and development is a complex interplay of various dimensions, the modelling of which is very difficult. We need to set directions of R&D by identifying critical and growing sectors such as Bio-technology and Nano-technology and develop a critical mass of resources to achieve them.

I am sure that the point of conference deliberations is clear as we need to develop a strategic plan to develop India as an R&D platform and power.

Prof. V. S. Ramamurthy, Secretary, DST

I will just highlight few points which come up repeatedly in a discussion of Science and Technology in India.

India as a global R&D platform is no longer a speculation as institutions, business houses and governments across the world are redefining their organisations based on this assumption, along with campus recruitments by global players etc.

To the question, are we prepared? I can say yes, because through sheer demographics we will have the population but, we need the right type of training. Thus, Human resource Development (HRD) must be emphasized. Therefore education must be excellent and relevant and must permeate the whole education system from schools to research organisations for basic and continued learning for researchers. Intellectual property generation is also important since we cannot be just exporting manpower. For this HR must be developed for India itself through patents and papers rather than just exporting them.

We have stagnated in S&T compared to China, hence we need more and better facilities which is become more expensive. Thus, we need to focus on shared facilities through "nano" networks of individuals and institutions, rather than dedicated facilities. Also, we need to focus on using international facilities like we have done in high energy physics and Astronomy. This will require new standards on performance, responsibility and working on a team, as well as giving international status for Indian science. Indian scientists also need to start focussing on entrepreneurship for S&T (we have 20 entrepreneurship parks in the country when we need about 2000) in addition to research as is done in MIT. If we put all this together, we can do what needs to be done in Indian science.

Mr. Kapil Sibal, Hon'ble Minister of State for S&T, Ocean Development

The question to ask yourself is this: Is the scientific community an endangered species? I ask this because science and interest in science is on the decline all over the world. One of the reasons is because we have not been able to demystify science. It is not user friendly and so the teaching of science at the school level itself needs to be changed to revive interest in science.

When we talk of India's competitiveness we have to relate it to where India is – where are we placed, which areas are we moving ahead, what is it that S&T can do for those areas, which areas are of relevance for the next 20 years are we prepared for them and what use can we make of them?

I was in Iceland recently and geo thermal energy is an easy resource for them due to its placement and accessibility and they have become extremely competitive in that area. Similarly for us to develop we need to look at our own needs as a country and what resources we can leverage, where can we partner with industry.

In the next 20 years I can see oases and lots of deserts. The oases are IT and ICT and we need to leverage that by investing in it to take it forward; pharma sector and bio tech have infrastructure that will allow us to take off in the next 5-10 years but needs good policy to take it forward; solar energy is a potential area that has still not been exploited and is an important way to deal with energy crisis (the 1 lakh Tata car will be using energy and having detrimental environmental and energy effects on the country.) One way to deal with this is to invest in solar energy and this hasn't taken off because the political class has not given leadership to solar

energy and also because scientists have done nothing about working to leverage it with government and industry. So scarce energy is the reality and we need a national energy policy rather than separate departments of power, atomic energy, water resources, petroleum etc. Textile industry has been provided with good incentives and is already at the threshold of takeoff. But we need to capacity building across the board to make it competitive also.

Solutions for all this is going to come from nanotechnology for which we have no institutes and infrastructure. We need a national commitment on that since it will impact on advanced materials and health sectors. But at the basis of this is the fact that we need scientists of calibre to do all this. Historical perspective is that almost any nation in the world until 1560s had GDP that was almost the same. Development of steam engine allowed some nations to move forward and it still took a couple of centuries for this to be converted into wealth for the nations. Electricity and other scientific revolutions also impacted agriculture. Rural economics was affected by fertiliser revolution and there was migration and urbanisation with increased leisure. Finally with the invention of the mouse in 1964 science has changed so much that political class has not been able to keep pace. In fact science itself is feeling the strain of keeping up with IT and ICT change in India. The next 20 years will bring unconceivable changes.

Americans and Europeans are far ahead of us in this regard. They are service-oriented economies. Service economy is the reality with 70 percent being involved in it. Manufacturing and industry in the conventional sense is of the past. Although India has a service economy component we are still at the lower end of the value chain and are still serving the West through call centres and BPO. Netherlands has a GDP that is equal to ours with a population of 60 million people. We need to become more competitive. Manufacturing of the West uses low cost resources in India and China and their service industry uses low cost human resources from these regions, yet we call ourselves competitive!

As a politician and layman, this is where I want the emphasis to be: We need to understand how we should become really competitive, not like this. Dream a dream, show me a vision and a road map to make us a major player in the world and I will work for you to make it come true.

Prof C. N. R. Rao, Linus Pauling Research Professor and Honorary President, JNCASR

This kind of meeting used to occur a long time ago – working scientists, managers, industry barons used to discuss for a day or so about issues we should be worried about. After 1985, this has not happened. – No discussion of issues in a concerted manner like that. Therefore, we decided that we should reinstate that meeting so people could talk in a free manner.

We need to focus on the vision we have for India in 20-30 years, and connect it to the likely scenario in India. I will speak as an individual scientist. Are we competitive as individual scientists working in India? Can we innovate in India? Also we have to keep in mind that given the demographics of population, most people will be young and we will be the youngest nation in the world. How can we capacity build for them? Secondly who are our competitors? We can see them – China will be a formidable power, South Korea, Singapore. We also need to see the connection between high GDP and good S&T. China wants to flood the world with Chinese scientists – US academia is already filled with more Chinese than Indians. We need to ask whether we are competitive in science. 90% of the world science is in small and medium science, not large transnational labs or "big" science.

How is India doing in science? India is not doing well in science –

- 2.7% of world chemistry is does in India compared to China 12% and US 23% in terms of actual papers being published.
- Number of Ph.Ds in IITs is maximum 50-60 per year with 300-400 faculty. Brazil is producing 10,000 Ph.Ds in basic science and engineering per year. So we have to produce more Ph.Ds and publish more.
- We have to do great basic as well as applied science, have more patents.
- IT revolution has occurred because of large pool of Indian engineers. Multinationals come because of this quality of manpower which is on the decline.
- Institutions haven't functioned well administratively. Globalization will succeed only if we improve ourselves in this area of bureaucracy too to make ourselves competitive. Have a different structure of administration for S&T by making them more committed to the country and enabling them by giving them responsibility and time to execute.
- Citation of Indian science is low.
- Scientists need to increase work ethics and culture. In terms of policy how to make scientists work beyond the call of duty? Older scientists have not been good role models so we need to show by example.

To address all this, we need to take harsh measures rather than invoke incremental changes in policy, institutions etc.

My own vision is that India does not have a big chance in manufacturing and the one sector where we can be competitive is in the area of providing knowledge workers for the world. We have certain benefits in this area even vis-à-vis China and Japan. Let large numbers go out – we can produce all the engineers for America, there's nothing wrong with that – but we need to constantly produce more of them. We should focus on capacity building and sheer numbers from which we can generate revenue. India can then become a power of a different kind in the future.

PANEL I
IS INDIAN SCIENCE COMPETITIVE?

Chair: Prof. P. Balaram

Performance indicators - Citation Index/Impact Factor - Mr. S. Arunachalam

The answer to the question posed by this panel is "No, we are not competitive". I will give some statistics to back this. In chemistry, India's contribution has come down from 3.4% to 2.3% of the world share now, based on chemical abstracts, while China has gone to 12%. Other countries in the region, China and Japan, and other developing countries elsewhere, like Brazil, have gone ahead of us.

India's share of the world contribution in science is maximum in agricultural science 5.48%. Relative impact as compared to world average is minus 68. If world is 100, then India is 32. In all the 22 fields, the impact of Indian research papers (as measured by the number of citations divided by number of papers) is less than unity. In material science we are somewhat close we are short by 31 %. In physics, we are minus 24 so we are slightly better. Between 99 and 2003, India published some 86,446 papers listing at least one Indian author. Of this highest was in agriculture.

Overall ranking of India, of papers published between March 92 and 2005, India is 21 in terms of number of papers published, in terms of total number of citations India is 13, in terms of citation per paper India is 119. So impact factor is very low. Given that science is a co-operative and competitive activity and we need to stand on the shoulders of others to proceed and we also want patents before others get it, citation is important. It also shows connectivity between sciences and scientists.

Recommendations

Although many people question the use of these technologies like citation and impact factor, they are important. People may mechanically use data from citation index and come up with rankings, which are way off mark because they don't know how

science is done. However, the fact is that we need to use the same yardsticks others in the world do.

Also, we need others to see the work we do. Many journals are not easily accessible to all libraries for resource reasons. One way to get away from this is to use open access archiving for increasing the visibility of papers.

We also need to set up independent bodies such as a science observatory much as the European countries have, to see where scientists are publishing and what their impact is. Competent people can monitor it and scientists can oversee it. We need to change the science policy in India.

Institutionalising Competitiveness

Dr. V. Sumantran

First, we need to see how we assess Competitiveness? Competitiveness may only be assessed in the context of measures. The most enduring measure is its impact on society through values given to material results (life expectancy, communication, etc.) or through intangible results (Aesthetic pleasure)

There is no denying the fact that science has shaped the way we live. There is no dearth of examples of how society has benefited from radio waves to wireless communication,man-made polymers, quantum physics to lasers.

There are numerous examples from India itself. There are a number of success stories. Because of an emphasis on indigenisation such as the nuclear energy programme, space programme, Green and White revolutions etc. Yet, we agree that India has lost a lot of ground over the past two centuries

But although there are pockets of success, where are the Grand Successes? Can we create the "field" or mechanisms that will provide alignment for the dispersed pockets of talent and creativity?

For this, we can use a **"Natural Economy Model"** or we can use a **"Mission Model"**

Effectiveness of the "Natural Economy" Model – example is of the Silicon Valley where there is a natural field to drive competitiveness.

- Natural Economics at play
- Society "votes" for specific technologies
- Dramatic improvement in performance
- Acute market competition
- "Self-fulfilling" prophecy

Effectiveness of "Mission Mode" – example of "Man on the Moon"

- *A priori* definition of objective
- Breadth of technologies
- Source of investment in Science
- Network of organisations involved

So how do we institutionalise competitiveness in Science & Technology in India?

Can Pharma & Biotech pick up from IT? They too are subject to competitive market conditions, they have a large pool of trained personnel, low investment, all of which can give us another success in India. We need to enable this by specific actions:

- Foster competitive market conditions
- Protection of IP
- Incentivize investments and R&D
- Improve education and HR development
- Leverage large human resource pool

There are also adequate options for "Missions" in India such as,

- Clean water for every citizen by 2010
- Infant Mortality levels at developed country levels by 2012
- World's best levels of Energy Efficient Economy by 2015!

These need to be backed by specific actions

- Ownership of goals at the highest levels in the country
- Mechanisms to ensure sustainability across economic & political cycles
- Ensure linkage to the entire value chain

- Identify and invest in critical enabling or *game changing* elements
- Make funding dynamic with respect to *risk* and *progress*

Recommendations

- Plan for both "natural economy" model and "mission modes"
- Engage the interests of the larger population as early as possible
- Reinforce education and skill development initiatives

Place of Creativity and Innovations in Science – Setting the Trend

Dr. Gangan Pratap

Creativity is something more than having an androgynous mind. I will give a more abstract explanation about it using the C. S. Peirce's concept of. abduction from the philosophy of science. Hypothesis formation is a process that involves abduction and according to Peirce, this is the creative jump. I will describe some of my work in relation to this. I submit, that Indians are very good at logical processes of deduction, which explains our success at IT, and somewhat good at induction but we are not good at all at abduction. Moreover, creativity and innovation are not routine activities of science for which we need unconventional individuals rather than systems.

Culture of Excellence

Prof. Sundar Sarukkai

I will focus on certain aspects of institutional building and institutionalisation, particularly in the scientific sector, as an observer of science, but also as part of philosophy and sociology group of science that tries to understand the nature of science in India and its status in the world.

If science institutes continue to look at science as an island separate from the rest of culture, then they will be mistaken. The lack of excellence in our culture is also reflected in other sectors and is extremely troubling. I want to suggest some ideas on excellence for you to reflect on.

Individual creativity does not lead to scientific excellence. While they are important, the idea of establishing institutional structures is really more important as they will *enable* individual creativity. The problem is with transferring individual vision to institutional ways, as has happened even with Gandhi and his institutions.

Institutions are always something more than sum of the individuals, especially in the Indian context. There is no rule for creativity and we cannot create individual creators. But we can create institutes as models of excellence. The osmosis and network benefits that are created due to institutions are deeply influential in creation. Individuals feed off a creative group of people who are related to the institute.

In the context of Indian institutions, this has been an impediment to scientific development – institutes cannot function as institutions; cultural parameters reflect in our behaviour in institutions; personalisation of institutions is very common and the importance of hierarchy is an impediment to creating the excellence in institutions.

Indian institutions are not only **paternalistic** but also **patronalistic**. There is a preference for **"nodders"** over independent thinkers; jobs and salaries are given as individual favours rather than as administrative, institutional procedures; reward systems is also similarly biased; there is no culture of dissent and no mechanism which enables its expression; we have forgotten that when we dissent it is not with individuals but with systems; there are no networks of institutions to form consortiums to work together on large projects and if they exist entry to them are monitored on a personal basis. There is thus a crisis of confidence among students and faculty.

Recommendations

- Reform institutions by mandating parameters such as transparency, uniformity and consistency, using models from all over the world.
- We need to establish a powerful network to enable things as library access across the board.

- Universities are the hope – we cannot let them go so we have to strengthen them as centers of excellence. Senior and retired professors should involve themselves to improve the institutional culture of universities.
- Strengthen academic culture in all disciplines rather than focussing only on science.

Chair's Remarks and Open Discussion

From all these presentations, the answer to the question posed to the panel seems to be "No". The Scientific Advisory Committee(SAC) under C. N. R. Rao has been doing a lot of things. The Science Observatory is a very important recommendation. We need to develop other measures in addition to science citation index. If indeed science is performing as well as IT as Gangan Pratap has said, then the image of science should also be similarly good. We must focus on greater output. One of the reasons to deride citation index is because it focuses on quantity – but we must be equally careful that absence of quantity does not automatically imply quality.

Performance indicators also could have measures like patents, technology transfers, revenue earned, power produced by nuclear science etc. We just need to take a harder and closer look at the performance of Indian science and at setting targets. We need a lot of new energy to come into science through natural economy or mission mode or whatever. As Director of IISc, I have been asked what are we going to do with all the extra money we are getting. I feel that one must be extremely realistic about what we are doing and set reasonable targets. We can thus modernise some parts of IISc but we cannot transform it into Harvard or Stanford. On the other hand, faculty want the 100 crores but don't want to be asked any questions.

- Citation index can't be only measure of competitiveness or quality because it is not fully accurate as shown in country listings for space. They are not the final word.
- We have to set realistic goals and we can increase competitiveness through such a mission mode approach as the space program has shown.
- Indian high energy physics community has participated in the international collaborations and the results of this can

be seen in the citations for this field where India is as good as China and South Korea.

- We need to set up some mechanism for university and institution collaboration like CNRS in France where professorships salaries are supported by a national organisation.
- In industry we don't worry about papers, citations, we worry about how much money is it going to generate. When we work with institution, we have to tell them to first file for patent, rather than paper publication, which is their priority. Also we wonder about how to reward scientists and manage them.
- Youth in science is non-existent. Perhaps the success of IT may be ascribed to its youthfulness. If a person's best work is done in youth, then we need to give them space and opportunity to do it and recognize and reward it.
- It was felt that youth was not an issue as IT also is slowly getting second generation oriented even in IT. All organisations and industry age. We need dedicated, hardworking individuals and we need to encourage creativity.
- In China everyone wants to publish because they are getting paid for it. In nanoscience, 60% of publication is from China, and of this 75 % is mediocre but 25% is good quality, so Chinese strategy is to publish more and worry about quality later. The problem is that we have marginal levels of excellence, and not enough numbers of them and this is why institutions have decayed.
- Vis-à-vis encouraging creativity, the MIT programme in robotics has been replicated in IIT-Madras and they are doing a tremendous amount to get students excited about technology. Opportunities are plenty for science but we need to work creatively to bring in the creativity of the students.
- We need to be aware that Chinese have a different political system so perhaps we shouldn't get carried away by them as our challenges are different and bigger; or maybe we are being too defensive about ourselves vis-à-vis the Chinese.
- How to make science an attractive career in India? Mismatch of salaries between industry and academia needs to be addressed.

- We need to understand the politics of citation before using it to evaluate performance in science. We need to institutionalise collaboration such as what happens in credit sharing in public-private partnerships.
- In terms of resources and targets, individual scientists need to determine these so there is a commitment to delivering something specific rather than disbursing 100 crores among the scientists.
- Mandate open accessing for all government funded projects.

PANEL II
SCIENCE IN THE WORLD AND IN INDIA: SOME EXPERIENCES

Chair: Prof. R. Narasimha

Science and Technology in Japan: Lessons that We Can Learn – Prof. K. Chattopadhyay

Japan in the post war period concentrated on D of R&D with neglect to basic sciences.

The academic structure was inherited from a German model, a country for which post Meiji Japan has great regard. The immediate post war emphasis on technology development was aimed at making Japan industrially competent.

In Indian circles, often the vision of Japan is that of a technology driven education. Unfortunately this is far from truth and misses an important trend culminating in what is often termed "third revolution".

Japanese R&D can be divided in three stages:

Stage 1: End of second world war to ~1970 rebuilding economy

Stage 2: 1970-1990 – consolidating and taking shape as an economic power and investing a lot of money in industrial R&D

Stage 3: 1990-present.

In 1995, Japan had problems similar to India with poor labs, bureaucracy etc. and the economy was still in deep recession. Japan's Parliament did something unthinkable. On its own initiative, it enacted the "historical" Science and Technology Basic Law announcing that it would increase government research and development (R&D) expenditures to 17 trillion yen (roughly $150 billion) and 24 trillion yen over the next five years. Japan's Diet, "The Science and Technology Basic Law.

Vision

Achievements in basic research aimed at discovering new laws and principles, creating original theories, and predicting and discovering unknown phenomena are in themselves valuable as intellectual assets to be shared by all humans; the results of basic research contributes to the advancement of culture and at the same time provides dreams and hopes for people. Such new achievements at times radically change technological systems or even create completely new technological systems, bringing about various positive spin-offs for society. Deep understanding of the human race and nature constitute the very foundation of human development, based on harmony between man and the environment.

Thus, Japan formed a national consensus on S&T and promoted education in S&T with a focus on internationalisation.

What drives Japanese Research

1. Wherever research is funded, it is fully funded and focussed. There is an emphasis on major funding of competent individuals and encouraging them to network into groups. Funding is also now being given to small group networks.
2. Emphasis on a very large volume of work. In the field of experimental science, Japanese researchers conduct very large number of experiments on fairly routine basis. Serendipity and probability of a new find is much larger in such a situation.
3. In general, Japanese researchers take extraordinary care to ensure good quality measurements. This is backed by a tremendous infrastructure for tool development and instrumentation, which are heavily supported by governments

Government funding, particularly competitive research funding is mostly basic in nature. Contrary to popular belief, even in the early days, individual researchers who had competence played central role. For example a series of major research initiatives in early days named directly after the investigators like Ueda project on fine particles or Masumoto project on metallic glass. In recent times, the emphasis is more on network where small groups of individuals play a central role.

How Japanese Researchers Collaborate with Industry

Once a basic expertise is established, the industry directly interacts with academics. Often researchers from industry are deputed in the professor's laboratory at the initial stages. Once the feasibility is established the action shifts to the industry with professors still playing the central role. Patents and sometimes papers are jointly published and financial benefits of successful innovations flows to the academics. As far as I have seen, onus of industrial initiative is not on actual researchers. The initiative invariably comes from the industry and programme develops from mutual interactions.

Research Manpower

Japanese Universities have very large number of Postgraduate students and less number of graduate students. The graduate studies in Japan are not funded and students often have to take a loan. Thus, there is a greater preference for the student to take up jobs and only highly motivated ones come to doctoral research. The research even today depends quite a bit on the research assistants associated with the group. They are equivalent to the Post Doc. cadre in the USA system but having more stability. Japanese Universities have very large number of Master's students and less number of doctoral students.

Research Planning

Research planning in Japan like USA is an elaborate affair with a lot of brainstorming. The future directions are debated fairly early through constitution of Brain trust. For example, there is already groups deliberating on Japanese response to Post Nanotechnology era and how Japan can plan to take a leadership role in the future development. This is the kind of planning we need to do to have some impact on the world arena.

China

S. Arunachalam

I will just make a few anecdotal observations: Unlike India, **China has a language problem** with the world since they do most of their work in Chinese. But once they realised that they are missing out on publications and citations, they have started translating into English in the Institute of Science and Technical Information in China and they have developed their own citation index since most of these publications are not included in the citation index.

They have an openness to ideas and their execution: Contrary to popular opinion, the Chinese Politburo is prepared to listen to average people who lack political position and they can even decide policy.

There was a time when they wanted to improve quality of learning in physics and they invited 20-30 brilliant young physics students from all over China and they also invited half a dozen visiting scholars from all over the world and let them interact over a few weeks.

Recently, they wanted to go ahead with open access archiving and they didn't have enough experience within China and so they convened an International conference under Chinese Academy of science and invited 21 experts from all over the world. They are now moving ahead with a nation-wide open access archiving system.

For the past ten years, I have been working in ICT enabled development and they invited me and two others and we went to small towns and met with 50-60 people in the field with the help of a translator who spoke very good English. When I asked her about her proficiency, she turned out to be a foreign educated Vice President of a company! So it looks like no matter where the input comes from, they are willing to listen and use it as long as it is useful.

A number of Chinese watchers including ISI (Institute of Scientific Information) have produced information on science in China. Between 2000 and 2004, China accounted for 4.66 % of world output, India for 2.32%. They are strong in material science accounting for 11.56% of world output without including papers published in Chinese language journals. Relative impact is also quite good.

Over a ten year period 1995-2005, China ranked 14 in total number of papers, 8 in total number of citations and 123 in number of citations per paper. Situation is similar to India. But if you look at individual years and you get a different picture: the last few years the curve with respect to China is zooming. Last year, India had 22,000 papers while China had 57,000. Ten years ago China was way behind India. Highly cited papers are also on the increase at a rapid pace: from 21 in 1994 to 33 in 95, 38 in 96, 46 in 97, 52 in 98, 59 in 99, 112 in 2000, 144 2001, 186 in 2002, 223 in 2004.

Among other science watchers is the **Science Attache of the US embassy in Beijing** who makes a periodic report for US government on science in China, which is both a scientific and a sociological analysis. It describes models, roles of different organisations, recent trends in funding, recruitments, achievements in key areas and its implications for the rest of the world. We need to do things like this – we need to know where we are with respect to the world as well as how well the world is doing.

The proposed Science Observatory for India must also must include collecting data of this quality about what the rest of the world is doing. China is also attracting expatriate Chinese by offering them better research facilities and perhaps we need to do that.

India

Prof. Srikanth Sastry

To begin with a disclaimer: Personal experience and impressions; and a caveat: Exceptions exist. But attention has to focus on the rule.

When I look at the state of science today, I need to see it through some indices of health such as the generation of ideas and the time lag between generation of an idea and carrying investigation to completion.

The good news is that we have a consensus policy on supporting science and technology, a vision of role for science in society, substantial funding, sizeable community of scientists, examples of accomplishment, freedom for pursuing scientific agendas, institutions for organization and support of science, and a desire to excel.

The bad news however is a bit more...

- **Goals:** Need better articulation of distinct goals for basic and applied research. There is a confusion about what we ought to be doing and the kind of justification that seems to be necessary.
- **Vision:** While there is a certain idea of what S&T is good for in the societal context, this comes from a political ideology that hasn't changed over the years or from the nexus between science and industry. The well being of the society at large has a stake in S&T and vice versa but that element is beginning to be a bit obscure. We need a debate for renewal of this vision and a discussion of other viewpoints which are very essential but do not percolate within the community or across its boundaries to include wider participation.
- **Funding:** Adequate, but rigid (often unclear) terms of use. Arbitrary (no discussion) decisions for partial funding. Uncertain time line. Makes planning difficult.
- **Community:** Not enough 'enabled' scientists in many areas who do full time research. So there are not enough numbers of active scientists to form intellectual communities.
- **Institutions:** Academies, journals and other fora where issues relating to science can be discussed – here we do suffer from lack of autonomy of opinion, debate because of close proximity to government.
- **Support and Facilitation:** Professional administrative and technical support inadequate. Given the large demands on time for putting in place *prerequisites* to research, active facilitation is a crying need for high quality research.
- **Administration:** Hierarchical, bureaucratic, unresponsive.
- **Evaluation, Recognition:** Rigorous and impersonal evaluation systems are not *evidently* in operation.
- **Work satisfaction:** Limited by the above factors.
- **Remuneration:** ***Sufficient if work satisfaction is guaranteed, but may not be sufficient to attract new blood.***

Recommendations

We need to build model science institutes on Academies rather than government organizations. Because of history, Indian scientific organizations carry stamp of both. This has had significant consequences: While scientific interaction is not affected, ability to arrange prerequisites for research depends to some extent on position and on initiative. There is insufficient debate on directions of research across community and this is turn is subject to vicissitudes of bureaucracy.

So we must consciously towards academic model. In terms of other areas the following are the suggestions:

There must be an autonomous agency for scientific funding. We must involve scientists of all ages, based on scientific merit, both in planning and evaluations. This should be temporary, and by rotation. There is a conscious need to cultivate a sense of stakeholding and this will have a positive impact on the morale. In terms of integration with universities: French CNRS model may be one way to do this. There must be support by national agency, which hires people but does not decide where they spend their time. Placement could be in universities. But there are mechanisms for mutual benefit and this model also offers flexibility in formation of symbiotic groups. The bottomline: Quick and definite response to needs of young scientists with their involvement in building the system.

We need effective facilitation. We have to accept that this is a fact of life: Everything takes 100 times more than it should. But the direct consequence of this is the time lag between conception and execution leading to frustration. We need to acknowledge the need for 'professional' support systems in administrative and technical matters. This will need more investment to support the support systems, but must be prioritized as time and leisure are crucial to creativity. In specific regard to the movement of scientists, the visa regime needs a major overhaul.

Funding a necessity. There must be heavy initial funding without strings and a flexibility to use funds. Accountability need not be sacrificed but quick and helpful response is needed. The criteria for

funding may be past performance, to avoid straight-jacketing (change of course, applications), but be rigorous in judging accomplishment which in turn should have consequences for future funding. There should be a promotion of collaborative activity through funding, and academic component [e. g., Nanoscience meetings] in order to build communities and networks. **Focused funding is good, but with consciously flexible definition.** Locally, there must be a strong focus on peer groups existing within individual institutions.

Evaluation reforms have to be put in place. We need to evolve standards for first round evaluations, to avoid arbitrariness. Criteria should be composite. Even if practices of evaluation are good, they need to be widely known and open, to ensure transparency. Make referee reports available as a rule. We should not hesitate to use external referees for in-department evaluation when local expertise is not available or limited [E.g., US NSF seeks reports from Indian scientists in India].

India

Dr. G. V. Shivashanker

The fact that younger people have been invited for a conference like this is itself indicative of a change of paradigm shift towards one, which involves younger people, and that is a refreshing change.

I am a tabletop experimentalist. The future is in multidisciplinary processes. But while chemists and physicists have figured how to do interdisciplinary research, biologists haven't. There is a paradigm shift even in recruitment of faculty to reflect this movement towards interdisciplinary work but in India, barring a few exceptions, biology has yet to reflect this shift.

When we think about science in the world and India, the question is: Do I have the best resources to compete at the global level in my area of research? To which I must answer: Yes, and only limited by my expectations.

Having said that, what are the problems then? They exist at 3 levels:

1. Problems at the laboratory level:

- Scientific signal is far below noise, and a lack of peer pressure.
- Mediocre & conservative academic setting with low expectations.
- Lack of postdoctoral scientists who are the backbone of Western science.
- Unnecessary administrative hurdles which tend to be boundary conditions for the pursuit of science.

2. Problems at the Institutional level:

- No mandate to develop groups of excellence (examples: solid state chemistry, condensed matter theory or liquid crystals).
- Very unfocused faculty recruitments and we have to change this.
- There's money & intellectual freedom – but complacency prevails even in the best places. The morale of a working scientist is very low – why ?

3. Problems at the systems level:

- Table top experiments: a niche for India but not respected. We need to invest in it rather than on table top science.
- Lack of peer review & respect for innovation because we have no value for tinkering with things. The mediocre academic setting has led us to follow non-innovative scientists.
- Barring exceptions there is a lack of good working scientists as good managers of science in modern India.
- Lack of long-term vision for growth say 10-20-30 year plan.

The question of nationalism should be thought of as an Indian working everywhere, you can still get prestige for India.

How do we move forward? We need to think about the following questions:

- Build more universities & institutes?
- Push for big science or tabletop science?

- Build scientists?
- Sustain existing universities & institutes?
- Build groups where India can compete?
- Invest in service sector ?

Recommendation

India's scientific future would rely on building groups of five to ten scientists in say fifty focused research areas (to begin with). Select the areas and people with caution and fund them generously. Provide these groups with the best infrastructure support and intellectual freedom, either in universities or institutes. Challenge them with the best world-class peer pressure. Establish global methods of stringent evaluation and accountability for these groups. With these ingredients, sizable fraction of groups will do interesting science and/or technology. Only then, we will have our presence & competitiveness felt in global science on a regular basis. Make this process a self-sustaining one and expand on this model. Else, we will only build a handful of stars for a billion population.

Chair's Remarks and Open Discussion

- If UK is spending so less compared to the Japanese, then what accounts for the Nobel Laureates in UK?
- Tabletop versus big science should be balanced rather than choosing one over the other. We should not neglect our international collaborations as in CERN. Spin-offs occur when working on large international collaborative projects. This has resulted in closely working groups in theory and experiment.
- We need to understand why the results in mathematics and theoretical physics are inadequate despite being low investment fields. Perhaps we need to do more focussed funding like the nanoscience initiative.
- It is a fact that very few people work in tabletop science and we need to encourage more of them.
- The quantum of funding has not given returns perhaps because we are constantly negotiating and bargaining on amounts.
- We need a good cadre of scientists who understand science rather than looking for good scientists who are also good managers.

- The 3 different science policy statements have had no effect on ground reality because they have not been accompanied by funding, unlike Japan, which is backed by massive funding.
- We don't work hard enough!
- We need a balance between scientific goals and administrative and technical support needed to reach those goals. The latter needs to be improved.
- India has a lot of talent, resources are adequate but we are not attracting more talent and we are not managing them well. US is really good at that.
- The productivity of the Indian scientist is low because the structure of Indian academic research has no post docs and students as Americans have nor Research Assistants or intermediate positions like Japanese have. Therefore we need to invent an intermediate position for Indian academics.
- We need to get others to work for us and one way to do this is by inviting international faculty as visiting professors and enabling this.

PANEL III
SCIENCE AND TECHNOLOGY INSTITUTIONS

Chair: Prof. P. Rama Rao

Role of Universities in S&T Strategies

Prof. Gautam Desiraju

Many speakers have spoken about impact factor but in general across the board we have not delivered the goods whether in labs, institutes or industry. This is because institutes have relied on a pool of students, which have been creamed off from the university system, while not putting anything much back in. The latter is the only mechanism we have for educating vast numbers of young people in India. Resources have gone outside of the university system and these have remained producers of "junk Ph.Ds". This has been compounded by the spread of junk education through coaching classes which actually do the work of educational institutions. For e.g., Ramayya Institute in Andhra Pradesh. This is the reality that we have to deal with. All this is the result of neglecting the university system.

We need a broad based liberal education at the B.Sc. level, alongside laboratory experience to tap into curiosity of young minds. Our education system teaches us to conform and we would rather become slaves outside the country.

In terms of recommendations, we have to take a serious look at China. How many chemists are writing in medium to good journals internationally and how many are getting cited? We have no presence at least in chemistry internationally. In China they are funding at a massive level. Approximately Rs 10 crores per chemistry department, per year and each department has about 1000 students divided between undergraduate and graduate education. Totally around Rs 10,000 crores is invested in 100 top universities, 8 of which are world class. So we really need a massive infusion of funds on a scale that is of this order to attract the students away from junk education.

Further, every successful entrant into a good educational system, such as IITs or the University even, has a number of "failed" students behind them, all of a good quality. What is happening to them? We need to address this vast number of students at a systemic level because what is happening in institutes is largely irrelevant to the rest of the education system.

Indians will have to find a solution that is suitable to us. Make a change in policy and find funds to the tune of Rs 10,000 crores per year to change things around.

Creating, Building and Sustaining World-class Institutions.

Prof. K. Vijayaraghavan

In this topic, the problem is with the terms **'world-class'** and **'sustaining'** because I think creating and building are fairly easy and straightforward. What is world class? Quality of research publications is one parameter of judgement and that can be evaluated by **citation index** other world class measures. Another way of seeing is if a **faculty member loses his job, would they be hired by some other university?** Third, is the **quality of students** and how well they innovate and whether they do well.

How does one define sustaining an institute? If a world-class institute can be sustained for 20 years or so, then it can be defined as a success. Around 5-10 years for building it and 10 years to become world-class. How to create and build such an institution? Particularly in India, creating and building an institute is relatively simple compared to sustaining it at a world-class level. Stagnation sets in easily. Why?

One of the key factors in preventing excellence or achieving world-class quality is that people forget the very strengths that made it a good place in the first instance. Peer group within the country is no match for comparing yourself with an international peer group. And local peer groups are not particularly good anyway. So you need **an international benchmark for such evaluations.**

The **ability for self-criticism** is lost in the long run. Scientists stagnate as they stop seeing themselves in a changing world of research. New areas of research come up and one must be responsive to this, but we are dismissive about it.

What we need to do is **hire aggressively**. But in India we hire people who look like ourselves. Growth is necessary but must be balanced with bureaucracy. You need to grow but remain small. One way to do this by limiting the resident time say 5-10 years and then they move to a local university as employees of the institute. If the institutes are located physically on university campuses then other mechanisms can also be evolved.

Undergraduate programmes on research institute campuses make them more competitive. Funding agencies must embed their institutions in a university environment so that they can bypass the university bureaucracy yet derive benefits of being on a campus and teaching. Universities will also benefit from this.

Culture of Scientific Institutions

T. Jayaram

I will talk largely of research institutions because that is my experience. The general level of incompetence in India is due to institutional constraints and aspects of the larger culture. Morale in an institution is a function of widespread competence and this is what we lack.

I will concentrate in this presentation on some micro-level (individual research organisations/sub-groups in large organisations) constraints on the Indian scene and some radical measures needed to overcome them. All the issues raised here may not apply to all the institutions. But they constitute some of the core negative practices of our S&T system. I will focus on a set of practices : administrative, managerial, governance, scientific administration. These are informed by a set of attitudes.

In **administrative matters,** government funding equals government department. It imposes on every aspect of daily life in an institution. Individual work is considered as something that individuals benefit rather than seen as something that adds to the knowledge base of the institution, country etc. Routine requirements like inviting visitors is something most often embedded in bureaucracy and considered as "projects". In atomic energy departments, if you aren't a project, you're off the radar.

S&T institutions have a kind of managerial governance, which makes every career subject to directorship. What remains unaccountable is the organisations who are responsible for how these institutions are run. Who governs the governing council? These are the ones who determine and create the environment that we work in and they don't get reviewed. They are not transparent, don't bother to reply to letters and have a mistrust of broad-based decision making.

Execution of trivia such as buying computers is something you are considered incompetent to do, even though you may have the best academic background.

There is such a bad attitude to paperwork, all done in good faith. To build an institution that can withstand the vagaries of individuals you need systems and procedures and a way to do scientific administration. Non-formal evaluations exist and they operate in promotions, which are all decided in an ad hoc manner.

We need to have a review of major institutions.

There is a burden on younger generation on generating excellence when they have no experience or exposure or opportunity to scientific administration. They don't determine their environment, policy, yet must generate excellence, which seems ridiculous.

There has been little pressure to change. We don't stand up to or resist bureaucracy, even in institutions. Time scale for change is a long ten to fifteen years.

Recommendations:

- Accountable, transparent functioning with an emphasis on written communication and giving reasons.
- Minutes of governing council should be made open.
- Broad-based decision making with inclusion of researchers of that institution on it. Trade unions are not going to evolve due to this!

- Younger scientists across the board must be included on everything. Without this no Diaspora will come back.
- Create an independent and articulate voice on science policy outside of the framework of the govt committee. And platforms to voice them.
- An anti-bureaucracy commission be put in place.
- Periodic mandatory science reviews of all institutions.
- Openness to change in functioning styles different from the past by a reflection by senior scientists.
- Building a larger critical culture.

Chair's Remarks and Open Discussion

- Universities problems have been addressed by M. M. Sharma committee and MHRD is looking into it to see how these changes can be made in a major way.
- How to double the number of good competent scientists in the country? Maybe the institutes need to take some of them and maybe we need a change in the state policy regarding this.
- Universities can be revamped but it surely is something more than Rs 10,000 crores. But the problem is greater than that and has to do with the fact that education has been put on the concurrent list.
- Evaluate results of funding periodically, and see how much of it needs to be replicated in the next funding. Quality of research can be determined by application potential rather than by publications in foreign journals.
- Change will come only if there is a larger view on science policy. We have no network or forum where a discussion of this kind can be held. So we need to blog. American Physical Society states without peer review no funding can be given. We can't even say that because we have no platform for saying it.
- In terms of sustaining institutions it is important to address sustaining excellence in old institutions. We need to seriously overhaul these, backed by review of science and administration. Recognize that old divisions of science are melting and there are new initiatives and older ones weeded out so a continuous infusion of ideas into science is on the cards. We need a modern management structure for all scientific institutions.

- Although smaller institutes can achieve all these – involvement of all from young to old, transparent reviews, greater accountability. But we need statutory and institutional protection for all these practices, because it can change overnight with a change of directors.
- Administration of our institutions has been done in a government style. Personal contact is on the decline. So yes, we need institutionalisation. Large part of the problems with science is the fact that younger people are not respected.
- Although the idea of institutes on universities is a good one, this should be formalised and regulated through some mechanism in the long term so that specific modalities can be worked out. Yet, the problem is that research institutes cannot take over teaching of small number of students at the university because they need to decide whether they are into research or into teaching.
- In our country, most initiatives and funds have originated from the centre. States have no money and therefore are weak. In the 10th Plan, the centre's allocation to S&T was 46,000 crores of which 12,000 was given to states. Again, when we say India's competitiveness, a large part of the country is being left out of the game altogether, For instance 70% of centre's money goes to 7 states. 55% of undergraduates are from 4 states. 60% of employment are in the IT and BPO that goes to the same 4 states. So there seems to be a repetitive distribution of resources among the same population and benefits go to them. Academic R&D accounts for only 2% of total R&D outlay and we need to make a strong case for increasing this share.
- In terms of sustaining institutions we need to look at selecting heads of institutions, the degree of autonomy that they enjoy in selecting these heads.
- Autonomous bodies and institutions, which are well funded, are doing very well on number of publications. This is because of autonomy given to researchers. Self-financed autonomous institutions, which are well funded with good leadership are also an alternative model for enhancing competitiveness.
- Look at the strength of the creative work force and develop a mission to build this pool. This is the only area where we can have a competitive advantage.

PANEL IV
COLLABORATIONS AND PARTNERSHIPS

Chair: Prof. R. A. Mashelkar

Transferring Technology to Society

Prof. Ashok Jhunjhunwala

I'm going to look at industry-research collaboration and how it can possibly result in world-class research. I will describe how a group of 15 faculty over the past 10 years have been working. **Start with a dream for India**. A science and technology supported corporate entity which creates a business towards the dream is a way to achieve the dream.

In 1994, we started talking about 100 million phones for India when we had only 7 million. We identified the local loop as the primary bottleneck and worked on it. We set up a corporate entity called MIDAS, which did a business of 1000 crore rupees. Similarly we did the same with internet kiosks in rural areas and that was easy but what was difficult to drive education, health etc so as to double the per capita income. We use video conferencing to connect doctors in urban areas to rural areas. To enable measurements of temperature, pulse etc, we invented a small box capable of doing all this. In terms of ATMs, we have created a product at Rs 50,000 an ATM compared to 10 lakhs of conventional technology. To empower people and make education happen in a big way in rural areas, we decided to focus on broad-band connection and achieved it.

For the future, we need to recognize that telecom countries in the West are receding and Indians need to create companies or we lose out on this. So we are going to build billion-dollar product companies to do this. We are also trying to build public private centres. All this has succeeded in attracting people from all over the world to work with us. India is a big market but at the right price point. We need to recognize this and innovate for it.

Industry-Science linkages
Prof. G. Thyagarajan

This is important because new demand and opportunities are coming up. Sponsored projects are fine but what we need is a look at the systemic coalitions between industry and research as IT has done. There are examples in Austin, Tampa, Atlanta.

Korea's growth was possible only because of massive manpower generation when universities were given a mandate to raise the research levels to that of industrialised countries.

Technology incubator models are also popular in the US and elsewhere. Canada's neuroscience network is another model supported by money. Network centres of excellence leverages intellectual resources to change the economic landscape of the place. Continuing education models for industry researchers may also be started.

How to make these models work?

- Matching should be there and a balance must be maintained between the creative aspects of science and the commercial aspects of industry. There could be practical difficulties in crossing disciplinary boundaries but these can be overcome through dialogue over time.
- Management of the project should be given careful attention. Trends in trade many compel industry to make course correction in the partnership map. Science should recognise and respond positively.
- Well-defined and realistic conceptualisation of projects is needed.
- Transparency is very important.
- Leadership is critical to the partnership.

Recommendations

A White Paper on industry-science linkages is necessary with new models of sector wise cooperation. There is a need to take stock of on-going collaborations and best practices in the business. Evolution of conceptualise models, suggestion of key areas for

research, institutions and key actors has to be done on a nation-wide basis.

Transnational Collaborations
Bikash Sinha

Giving examples of specific collaborative projects, Prof. Sinha showed how it is possible to do work in areas which require large investment and could otherwise not be done by a nation like India.

In small scale collaborations, we have partnered our colleagues from other institutions/laboratories in the world, resulting in by and large high quality research work (theory, experiment), e.g, cyclotrons, pelletrons, Radio-active Ion Beam programme etc. In mega-science collaboration, experimental collaborations have been at large accelerator centres e.g., CERN (WA93, WA98 @SPS, ALICE@LHC), BNL (STAR, @ RHIC), GSI, RIKEN etc

Excellent physics has been done through transnational collaborations and they have managed to tap into the creative instinct of young people. Spin-offs of these projects have been also there. Networks have been formed in the country and capacity-building of individuals and groups has been achieved. Foreign countries are coming to us for quality manpower. Individuals are not as important as institutions to collaborate. Now people from abroad come to our laboratories. Frontiers of technology are not built from a vacuum: science needs technology and technology needs science.

Information Technology and Science
Prof. N. Balakrishnan

Information Technology is a revolution that created employment for those otherwise unemployable, one that heralded the death of time and distance and redefined service and outsourcing. It is an opportunity for the developing nations to become "developed"

In the developed nations' perspective, it creates Tomorrow's Technology using Today's Technology. The basic ingredients are

Today's Technology, Cutting Edge Science and Human Resource- all mainly intangibles. There is also a very large return on investments in IT.

At the frontier of technology is science. This is important because we must realise its repercussions: The Science Divide = The digital divide= economic divide= knowledge divide= Prosperity Divide.

IT and Science in fact make economic sense because scientifically advanced nations are also advanced in IT. Companies that invest heavily in science also earn more revenues and capitalize more. They work at the high end of the value chain- at the innovation level

Developing nations look for large employments- have a low science base and hence work at the low end of the value chain. Hence they have very low investments and entry barrier and hence face an uncertain future. We need to move up the value chain by investing in science.

List of Facts:

- Nation's wealth is determined by capitalization of its companies (both tangible and intangible) rather than by revenue alone.
- Revenue per employee of Indian IT majors is around US$ 50,000 to 60,000 per year.
- Revenue per employee of IT majors elsewhere is around US$ 250,000 to US$ 600,000.
- Successful companies that capitalize more also have more patents and more Scientists (Ph.D.s) employed.
- For Nations to become advanced, they have to spend more on ICT and produce more Scientists (Ph.D.s).

DIA THAT HAVE APPLIED FOR INDIAN PATENTS SINCE 1999

So, countries with large science base are also the wealthiest. They invest largely in ICT, and also own ICT companies that create more patents. Knowledge multiplies, therefore we must invest back in science. We need to relegate low-end – mundane – data level – service level jobs outside - earn more. We must innovate and all

future innovations will lie in the interface areas between science and engineering

IT grew out of the convergence of several things such as the convergence of applications, convergence of networks, convergence of devices and all are proving to be location, time and language independent access. Growth is so fast that it is hard to keep pace. Now Internet alone is not enough, we need Wireless Data Services Access and so on.

There is a digital convergence towards smart devices. More and more devices become cheap. One-chip components and different devices are joined to form new multi-purpose devices which converge with applications to form digital personal tools.

Behind digital convergence is the drive towards Material Convergence and Natural Interfaces. Can silicon do self-replication, relay sophisticated emotions, smell and express trauma, predict future, motivate itself? Here the convergence is of enormous computing power, manipulative advances in physical sciences, revealed mysteries of genetics. Can silicon do what carbon does – Yes, if science is added to IT.

The paradigm shift in computing is that they are becoming almost human.

A few examples of "Grand Challenges" in IT waiting for science to solve

- Moore's Law
- Sensor networks
- Scalable entertainment – How do we multicast to a billion people
- How big will Google grow ?
- Software
- Recognition Versus Recall

There is a paradigm shift in software. In the 20th century, computer software was designed in large part to overcome hardware limitations. But in the 21st century, many of these limitations no longer apply. We have an abundance of computing resources. This is making us rethink how to build software.

Recommendations

- generate around 10,000 Ph.D.s in the next 10 years – a task that looks impossible. But we can and should do it. If needed in collaboration with world renowned Universities, IISc, IITs and NITs.
- Put science into IT – There is no IT without science

At the frontier there are no borders; in IT there is movement from it being a technology to becoming a science.

Chair's Remarks and Open Discussion

- We have to have our own model and build on our own strengths rather than emulating the Chinese or the Japanese model.
- While we do need Ph.D.s in great of numbers, what is the role of CSIR labs in creating this pool of Ph.D.s? Students who work on their Ph.D.s in the CSIR labs. We produce around 200-350 Ph.D.s per year and they are employed by industry. WE have a Human resource development (HRD) centre within CSIR and we are expanding its scope to also create an advanced science training for them. That is where the deemed university enters. A specific institution, which is committed to HRD is being given a deemed university status and the Ph.D.s who come out of this university will be such that the industry requires.
- We also need to ensure employment for the increased numbers of PhDs we produce.
- ICT's relation to GDP is murky because the countries with the highest GDP also having high ICT, but it may be going into entertainment rather than development.
- We need a national policy on IPR.
- We need to develop a team-playing attitude especially when we talk about collaborations and partnerships.
- Patriotism should be interpreted as great ideas are born here and the wealth created from it also remains here. We should not use our IQ to create IP for others.
- Government has a huge role to play in policy. New Millennium Indian Technology initiative points to private public partnership.
- Some Indians are doing well but the challenge is when will India do well? That is when we will be truly competitive.

PANEL V
SCIENCE AS A CAREER

Chair: Prof. V. S. Ramamurthy

Forward and Backward Linkages in Science Education

Amitabh Mukherjee

I will talk about linkages between school and college education and linkages between universities and the outside world. I will start with some questions:

- Why is school science often characterised as boring by students?
- How can we make high school science more interesting so that students are encouraged to take up higher studies in science?
- What is the relationship between school and college science education at present? What should it be?
- What should be the relationship between universities and society? In particular, what should undergraduate science education be like?
- Is there a conflict between the demands of equity and excellence? If yes, how can we resolve it so that we can move ahead?

A basic issue needs to be addressed in school science education: What is the primary aim of school science education? There are two important aims that are often articulated: One, to promote higher studies; and two, to train future scientists or at least to help students become scientifically and technologically literate. But are these two conflicting goals?

The globally accepted aim is Education for All (EFA) an important ingredient of which is Scientific and Technological Literacy (STL) for all. This suggests the goal of school science education cannot be primarily to produce scientists. On the other hand, in India, school science education is strongly linked to higher education, and is seen as preparatory to it.

Therefore there seems to be a conflict situation within science education in our country. Any attempt to remodel curricula, syllabi and textbooks to make them more in tune with the EFA kind of objective is seen as 'dilution'. Fears are expressed that this will adversely affect India's competitiveness.

Curricula and textbooks are overloaded with information because the nature of real learning in science is not appreciated. So what we need are curricula, materials and teaching practices that support learning, not teaching. Reduction of information load is a must from both points of view.

Now if we move to University science education, it is suffering from a crisis of relevance. Universities in India were rudely jolted in the 1990's when enrolment in science courses dropped rapidly. Science undergraduates often express the feeling that what they are doing is irrelevant. The university structure does not permit any interface with the outside world. Curricular structures are rigid, do not cater to variety in student population Small systems (colleges) attempt a big task (teach every course). There is no emphasis on autonomous learning. No way to learn what research really means.

Recommendations

The way forward is a university open to the world. They need a major structural change, not mere revision of syllabi. They must have a more flexible curricular structure as well as structures that allow collaboration between colleges, among universities, and between universities and R & D organizations.

We need to reinstate research in universities. The human resources needed for S & T in India can be met only when universities are engaged in research as part of its mandate. This is possible only when research is reinstated in the universities. To get enough people in frontier areas, we need a research-oriented attitude right from first year of college.

What makes science exciting is when students grapple with real science – with processes and not with information. Science is boring only when presented as a collection of facts. So doing science is the best way of learning it.

What about using IT: What about information? Don't we need that too?

Our information needs in the modern world can be met fully, thanks to technology

Therefore, science education must incorporate and take advantage of information technology.

In summary I would say that there is an imperative need for change at both school and college levels. To have real effect, *systemic* change is a must. Small experiments are important, but insufficient. Mindsets have to change. Hopefully, they will.

Incentives in Science Careers

S. Dattagupta

The word incentive, according to its dictionary meaning, is meant to relate to incitement, excitement, encouragement and this is the meaning I will use for this presentation. Some of the things I say will be repeated from previous presentations.

What is lacking in our country today is the inability of science to imbibe in young minds the passion for doing science. Science has to be a passion. Pursuit of science is about making discoveries, however small those discoveries may be. Even a child when she plays with Lego toys is fascinated by the new structures that she is creating. It is creation and creativity that is at the heart of the excitement of science. Thus science is no different from art and poetry.

Science is mainly experimental. It is all about understanding and interpreting nature through experiments and to make new predictions and create new structures. Experiments are done through laboratories, which require adequate infrastructure. Speaking of incentives, one must give students enough incentive to carry out experiments in a laboratory. There is a huge lacuna now in our university and college and school system of this. Thus our approach to science has remained largely ***"brahminical"***, by which I mean that there is too much on black board teaching and less on live demonstrations on lectures and teaching accompanied by laboratory experiments.

This brings me to the issue of "us" and "them" syndrome in science. Science in India is viewed largely as a white man's science because we in India went into a slumber for 6 centuries and became completely oblivious to our great traditions in science. What we have today is a youth that has lost its self-confidence. He does not know that he is equally as good as his Western counterpart. He is more keen to do bandwagon science by latching on to some famous Western scientist than by creating his own niche area. I can only speculate that this attitude is the result of years of subjugation by foreign powers. A young Indian doesn't feel proud to be Indian. How to inculcate pride in a young independent nation is part of what must be addressed when we talk about incentives in science career.

Another incentive is the need to create awareness in youth that science leads to technology, and technological breakthroughs spur further scientific research. Synergy and complementarity between science and technology is a very important hallmark of research labs in the US such as bell, IBM, Xerox. Transistor was a result of research in basic sciences but today the transistor revolution has penetrated the lives of our milkman who has a ubiquitous accompaniment of a transistor radio. Technology creates jobs, leads to improvement in lives but it comes as a result of research in basic science but it also can lead to further development in basic sciences. How does our youth visualize this symbiosis between science and development? This is significant.

This brings me to the conclusion that science and scientific research must be dovetailed with education at a very early stage. We must restore the glory of science universities wherein science is living and wherein lies the natural setting of creation and diffusion of knowledge. Science should be projected as an exciting way of life. Revamping science through committees are very laudable steps as is the creation of science institutes.

We need to link science with job opportunities comparable to engineering, IT and management sectors. Post independence, India has seen the mushrooming of research institutes under the aegis of

one or another DAE, CSIR DBT etc. But these agencies have not lived up to their potential because of lack of input from enthusiastic young people. This has happened due to neglect of science in university system. Jobs should be given by these various agencies for a few young, quality people from the university system. Continuing scholarships should be given to young and deserving students.

The problem has less to do with lucrative job prospects than with creation of opportunities for excitement of science. Practising scientists need to go to schools to talk to young people about science. How our stalwarts used it for independence struggle and did it in undergraduate teaching colleges must be communicated.

Recommendations

- Refurbishing of labs at schools and colleges is a first step and focus on early education.
- Reviving of skills in mathematics at schools and undo the damage caused on these skills by computers.
- Starting undergraduate teaching programmes at central universities like University of Hyderabad, JNU and IISc with large campuses. We have to reverse what TV Ramakrishnan has called the ***"trivarna"*** caste system **where undergraduation education is done in colleges, post gradratuation in universities and research in ivory tower labs.**
- S&T spin-offs must be leveraged by networking of research institutes and universities.
- Link science with job opportunities.
- Emphasise tabletop experiments in addition to big science. Ideas aren't small and this brings back experiments to colleges and universities.
- Lack of self-confidence can be addressed by sending them abroad on travel grants to see that they are as good as their role models in the West.

Status of the Indian Scientist

Vineeta Bal

The scientist is a product of his or her larger culture. If we want to understand the status of the Indian scientist then we need to understand the factors that go to mould them such as the following socio-cultural factors:

- Type of education – what have you studied and how have you studied it.
- Religious and National identities which we receive and how these factor into career choices. Children learn from these distinctions and hierarchies.
- Scientists expect respect from the community
- Quality of research work is not emphasized as much as we should.

We have a huge number of graduates in science but many are unemployed and at any rate, quantity cannot substitute for quality

Where do the problems lie?

Science education in schools and colleges

- We must nurture questioning attitude among youth
- Emphasis on reason and rationality
- Religion must not enter professional spaces
- Portrayal of women in the textbooks must be included to give a representative picture.

There is an inextricable linking of science with technology, which is a mistake. Expectations from society of science are different from that of technology. 'Returns' from science vis-à-vis from technology are never immediate. If they do good science then there is none of that notion of national pride as happens when we make a product. WE tend to glamorise nationalism and accept sub optimal technology. We must aim for the globalisation of science.

Impact of globalisation is a double-edged sword. It appears as if there is more money to have but poor are becoming poorer. However much salaries have increased in the past 15 years, scientists now also look for better paying jobs or getting second jobs in the family. Employment opportunities are not keeping pace with 'growth'. Scientists are now considered at best a good second job in the family. But the fact of the matter is that for whatever reason, many more women are aspiring to enter science research than earlier. We have to deal with the realities of this.

There are two independent job descriptions for every working woman – one at home and other at work. These have not been affected as yet by globalisation and need to be addressed.
Which roles do women play in science?

Majority of school teachers, college teachers and researchers are women. But look at how they disappear as the career progresses:

Parameter	Percentage
Women's enrolment in higher education (UGC)	39.4%
Women enrolling for PhD in Biology (NII)	60.1%
Women as post-doctoral applicants (DBT)	46.1%
Women in permanent employment (9 orgs)	25%
Women as senior faculty/full professor (ibid)	17%
Women in advisory committees (5+1)	12%
Women as members of Science Academies (1)	6.7%
Women as prestigious award winners (Bhatnagar)	2.3%

Why is the status of women as scientists relevant?

Recommendations:

What can be done to enable women to enter science in a gender-neutral fashion?

- Improvement in the educational style and textbook content
- To bring out rationality
- To bring about gender sensitivity
- To encourage independent thinking
- To encourage science research as a career
- To provide social and financial security in the profession

What can be done in a gender-specific fashion?

- Encourage girls to engage with science and prepare them for a lifelong
- Career in science
- Provide adequate social support structures
- Introduce evaluation systems for selections, promotions, awards etc. which are transparent and gender unbiased.

- Special measures to decrease harassment at the workplace
- Gender sensitisation programmes for all professionals

Strategies for improving prospects for women scientists have to look at these in a balanced fashion.

Challenges for Career Growth in Science

Dr. Namrata Gupta

There are 3 major influences on career growth in science

- Norms of science
- Socio-cultural context in which science is practiced
- Work environment in organizations (influenced by above two)

Norms of Science

Merton (1942) considered science as a normative structure; It is claimed that there is a 'Universalism' in scientific enquiry: personal attributes (race, gender, etc) do not influence the scientific community in judging contribution to scientific knowledge and that there are fair rewards for contribution; the career is open to talent.

But actually there is a lack of universalism in science because there are tacit aspects in practice:

- Citing is a way of demonstrating that the authors belong to the right circles
- Citation as one of the ways in which new knowledge is brought to the attention of the "core sets" (networks of scientists who are established in their own field and legitimise knowledge)
- Recognition skewed in favour of an established scientist
- Race, gender and personal qualifications enter in judging merit

Lack of Universalism

Women are less able to translate productivity into recognition: Holding productivity constant, women's rank and attainments - lower than men. Quantitative evaluation vs. qualitative - women publish less but cited more

Socio-historical Context

There are 2 key contextual aspects:

1. India as a hierarchical society (caste and gender); those lower in position – also a minority in science institutes
2. Science in India as an implantation, unlike in the west – persistence of traditional attitudes towards women and caste persist which influences work environment

Work Environment at Indian Academic Science Institutes is influenced by 'norms' of science and by the socio-cultural context. The work environment has two components: formal (codified and rule-related aspects) and informal work environment (contacts, networks, informal groups)

Tacit (hidden) aspects in the formal environment

- Unwritten rules in appointments and promotions (no couples in same department)
- Interview committees asking gender-related questions (on ability to cope, to do field work)
- Early achievement is enmeshed with domestic duties and most women publish more in their 50s when domestic responsibilities are less.
- Careers with breaks or different from the usual are discredited
- Lack of women in higher administrative positions (lack of power) and lack of opportunity to show their ability.

Tacit Importance of 'Social Capital'

'Human Capital' such as individual talent or merit is not enough for success: mentors (or guides) and informal networks as essential for success in science.

Significance of Informal Contacts

More Interaction implies more contacts implies more visibility implies more recognition implies more Informal Work

Environment etc in a loop. Minorities (e.g. women) lack informal interaction: face exclusion from informal networks (due to lack of critical mass, social segregation norms, expectation of stereotyped behaviours, etc.) Lack of interaction leads to lack of contacts, visibility and recognition. Lack of contacts affects collaborations, brings about isolation and a dependence on 'human capital'

Conclusions

Rewards / recognition not necessarily based on rational principles

- Contacts, networking and visibility important in recognition which disadvantages women.
- Isolation of women scientists (infiltration of social prejudices in the work environment + the manner of practice of science)

Recommendations

- Need to understand that women scientists have genuine problems.
- To increase critical mass by encouraging talented women at the Masters and Doctoral level.
- To encourage women scientists to take up higher administrative positions.
- Organized mentoring for women.
- To give due consideration to the careers off-the-beaten track.
- A more thorough system to recognize and reward talent among researchers needed, for e.g., by: Having more than one independent committee to look at the applications for rewards
- Active and well-known researchers (not merely high profile) as members of these awards committees

Chair's Remarks and Open Discussion

- If you want to make one's career attractive, you have to identify, nurture and provide an environment. Starting from home through school, college, universities and finally in the R&D institutions. Therefore, **addressing it only at**

the final stage, you will never be able to address competitiveness.

- At every level and sector, women are there and this is the reality. There are many at the level of enrolments and fewer at the administrative or powerful positions. The reason is because this change has happened only in the past two decades.
- There are some responsibilities, which cannot be changed but must be addressed such as mothering roles. But we can enable their participation. For instance, instituting flexitime and crèches. Understanding spouses can be helpful, but we have little control over that. There are things only society can do and there are others we can do. In the next twenty years there will be more women scientists than men and we must learn to deal with that reality and create an enabling environment.
- In one of the first items to discuss at Scientific Advisory Council(SAC) to the Prime Minister was the question of women in science and how to enable them to reach higher positions. Proactive changes were discussed along the lines of increasing fellowships and flexi time.
- Americans target early at school level through certificates signed by President, there are mentoring programmes for high school students and schools are encouraged to conduct some of their programmes at the university campuses. We should take out whole page advertisements in newspapers like the army and navy does, then it can make a difference – have a campaign to extol the virtues of science as a career.
- There should be more women in evaluatory bodies on a regular basis. In general, applications and proposals should be sent to external referees to overcome the gender biases. Informal behaviour must have codes of conduct in organizations.
- We should be thinking for immediate effect since things are changing very fast in the world. Secondly, when we talk of scientific minds we are thinking of very special minds and these do not reside only in urban areas. We must think of ways in which people staying in rural areas can be identified through the mechanism of the Academies. Take even 400 of them and make each one of them responsible for two

youngsters from middle or higher secondary school, who come from their area so we're not talking about a large number. They should be nurtured and if monetary funds are required a corpus may be set up to enable this. Thirdly, India is going to be a outsource point for youngsters and we may lose everything we have invested in through out migration. We must be prepared for this. Including women in this strategy is very important since they are more independent and may resist moving out.

- We are looking at only the symptom rather than the problem when we try to understand why women are not there after Ph.D. The reasons are not well understood and the implication that post Ph.D women are not taking up academic jobs is not necessarily true and is closely linked with reforming of institutes.
- Reforming of textbooks at school levels is required.

The Panel discussions were followed by a plenary session the next day. The working groups presented the summaries and this session was chaired by Prof. C.N. R. Rao.

Plenary Session

Working Group Summaries

Panel 1 : Is Indian Science Competitive?

No sector or institution will remain youthful beyond inception and the first generation. We need to produce more people and productivity. To increase creativity, we need to incentivize publication through money as China has done. Mobilize large quantities of people committed to science. World is filled with opportunities for science we just need to tap into students' creativity.

Although I am presenting only Panel 1, there are linkages between panels. There is agreement that Indian science is not internationally competitive. We should increase the volume of scientific output and not worry about quality. The peaks of science are around base, so if

we broaden the base, we will increase chances of peaks. If average output is increased by 10 %, then, automatically chances of peaks increases.

In the first half of 20^{th} cent, Indian science was lucky - though base was narrow, peaks were many – Raman, Bose etc. That time, science was a gentlemanly pursuit when a brilliant individuals working with small resources could scale the pinnacles of science. But now that period is over and in most areas of science, heavy investments are necessary for scaling peaks. Lastly, our competitiveness has decreased in last twenty years. My own feeling is that one need not have worried about this if the gradient of the competitiveness had been in the right direction but that is not so for gradient is negative. India is doing well in most other spheres except in science.

Something seems to have gone wrong: Career in science is perceived as less attractive than others. This is part of larger global phenomena, but for us the repercussions are more. Other sectors pay more, so this issue of needing to pay young people more has to be kept in mind.

More fundamental is the complete breakdown of undergraduate teaching. In the US, which is the world leader in science, Linus Pauling etc taught undergraduates just as in India, JC Bose and PC Rai taught basic classes in Presidency college and CNR Rao in IIT Kanpur. It is an electrifying experience to be taught by some one like Amal Kumar Rai Chaudhari. 30% of internationally recognised Indian theoretical physicists have been his students so that impact of teaching is more than that of institutes.

Opportunities for doing a good Ph.D. in India have increased now unlike before where in physics for instance, only a quality PhD was possible in Tata Institute of Fundamental Research(TIFR) 20 years ago. So up to grade 12, things are not too bad and at Ph.D. level, opportunities for doing a good research Ph.D. have actually increased. But there is a missing link in between, whereby those who are attracted to science in colleges and universities are not nurtured properly due to lack of good institutions.

Also, the lack of job opportunities for professional scientists was not discussed. This is serious since no new institutes are coming up and old ones have saturated so even bright Ph.D.s are not getting jobs whereas earlier even a mediocre scientist could get a job. Faculty appointment has gone haywire since there is no cohesive system of universities, which is differentiated at different levels. So while we have to increase the number of scientists in the country, we also need to think about how they are going to be absorbed in the employment market.

Also, there is the problem that when we become members of some exclusive groups or institutions we work to keep others out of this group. For instance, the attitude that IISc should not grow beyond this point. We should start an undergraduate teaching programme on this campus itself and increase the size of faculty and student intake.

Recommendations

- Improving undergraduate education by setting up centres in Kolkatta and Pune.
- Faculty movement from institutions to university at around 50-55 years of age. National scheme should be instituted for such a scheme.
- Basic issue of revamping the university system via the movement above and then participate in the recruitment to rejuvenate the university.
- Funds and remuneration – close correlation between fraction of GDP spent and output but the money should make it available to all sections and stakeholders in schools and colleges.
- Observatory for evaluation of science performance through citation as well as newer indices to do such evaluations to create a level playing field. Addresses of paper authors matter in citations, so we need to develop other indices, which may be free of them.
- Since studying abroad was such an experience for so many of us, we should also try to aggressively attract students and postdocs from abroad in the belt of Middle East to South East Asia for our universities and research institutes. This will give us better international stature.

Panel 2 Science in the World and India

Caveat: Elite institutes over universities

Science is actively encouraged in Japan and China with government funding. The results seem to be self-evident in increased scientific productivity. Thrust areas have been identified such as alternative sources of energy and these have been supported with adequate resources. Proactive support for international travel and publications exist in China, and thus international conferences are well attended by the Chinese. Further, they are paid for getting published in international journals.

Elite institutes feel that individual funding is adequate for them but even here there are unnecessary controls in the utilization of those funds for example, to buy a computer or hire a post doc, too many unwanted procedures.

Big science versus small science: despite the relative distribution between them, there is enough money to support a whole variety of them from table tops to large projects but the review of such proposals is not done professionally but by the directors of institutes who despite their erudition, may not be well versed in all branches of specialization.

Grants are not always given with the conviction in the responsibility of scientists to handle the money. Many of the grants don't support personnel (post docs, administration and secretarial), which is supposed to be drawn from institution itself. This also causes some hindrance.

There is constant infighting between scientists for funds since it is perceived that they are limited. This affects public images of professionals and we need a more co-ordinated scientific policy or vision document to address such issues. This can be probably brought out by the Academy of Sciences.

In Institutions, it is felt that there is lot of freedom. But the negative impact of this is that there is no peer pressure for achieving excellence and no penalties. Our benchmarks are national even in research institutes rather than international. No accountability for public funds but on the other hand there is no incentives for performing better since there are no rewards either.

The development of a critical mass of a peer group is necessary, and often there is not enough money to support the development of a group. Hence, one cannot recruit post docs since they are not funded from the projects but from institutes. So allocation of postdocs and financially supporting them becomes a contested issue on which no clear policy directions. Finally, there is low morale even in elite institutions and everyone is depressed about the future of science. This is because young scientists have been disenfranchised.

An important attracting factor is salary versus sacrifice to science: Intellectual satisfaction is now possible even working in corporate environment for a decent salary as compared to sacrificing yourself for science in institutes. Unless this salary differential is addressed, we may lose more people to corporate research labs.

Recommendations:

- Funding should be given at very early levels with freedom for a clear length of limited time maybe 2 years or so, and accountability parameters be predetermined.
- Changing National policy always takes time but smaller reforms can be implemented at individual institutional levels by reducing procedures and paperwork.
- Bring in active researchers starting from students and find out what are the factors that affect their work and careers and incorporate all stakeholders into drafting the larger policy making of science at both institutional and national levels in the country.

Panel 3: Science and Technology Institutions

I am going to take a sociological perspective – science as an institution and scientists working in scientific organizations with science

A set of norms serves as an important guideline. Science is carried out in organisational settings (guided by norms regarding sharing

of resources, divide time between research and teaching. Cognitive norms refer to what is the right problem to tackle at a given point in time,) which ensure social reproduction through students and post docs and faculty etc., Institutions must to recruit better faculty than the existing ones. It should be done through rigorous peer evaluation, rather than personal judgements.

Recommendations:

- Norms should be evolved through participation of scientists themselves in recruitment and mentoring of new researchers, and contribute actively to in policy-making at organisation and national levels. Procedures for internal evaluation and peer evaluation must be in-built processes. It is important to cultivate networks since innovation stems from networks and scientists working in groups.
- Increase legitimacy of science by increasing better geographical representation of scientists.
- Administrative staff should be trained and sensitised to appreciate the work and give appropriate support. Financial norms need to be liberalised and decentralised.
- Autonomy in administration is essential.
- Evolve well-funded R&D programs in science and technology.
- Ensure transparency, fairness in allocation of resources.
- Encourage and celebrate dissent and criticism rather than seeing it as a nuisance.
- Leaders should be competent academics as well as good leaders, and responsive and chosen by democratic processes. Decentralisation of decision-making. Representation of scientists on executive bodies through nomination or election.
- University system is the weakest link in the scientific education and must be transformed along the following lines:Infusion of funds for modernization of laboratories. A broad based liberal education must be introduced with continuous syllabus revision and restructuring of courses. Text books should be updated. Shift to credit system. Recruitment of faculty must be a proactive process.
- Universities need to interface with research organizations as an institutional arrangement rather than as individuals especially in matters related to pedagogy.

- An exchange programme that facilitates internships for university students at labs and research institutions, institute faculty teaching in universities and provision of university teachers to engage in research with protection of salaries will all prove very useful. Thus, a graduate programme of a total of five years that include one-year internship in research institutions can be thought of as a viable option.
- University Grants Commission (UGC) and the state councils of higher education must jointly revamp universities

Panel 4 Collaborations and Partnerships

Science and Technology supported corporations is a good way to enter rural areas. Vision makes a difference. Focus on market and innovate technology for it. This is the only way to progress in the free economy as compared to a socialist economy. Government's role should be HRD, by investing in educational centres for teaching and training people. Industry should fund product development.

The United States can be a role model for collaborative models. Several US university labs have been heavily funded by industries. In addition, stringent quality control guidelines have to be developed and followed. One cannot do this in an academic environment. Academic institutes are not designed for such focused product development - they are supposed to be functioning with full freedom and cannot be tied with too many regulations. Certain ideas tapping industry potential can be developed into products when there are such partnerships with the industry.

Recommendations:

- There are several models to increase interactions between academia and industry. Such models help foster relationships at the institutional level rather than individual level. **Develop Tech/knowledge parks within a university or institute campuses.** Physical proximity brings intense interactions and helps scientists become aware of ground realities and Intellectual Property

Rights(IPR) issues which scientists have less knowledge about. b) **Incubator models better interactions and take values of science research into market c) Entrepreneur university** – such as Georgia Tech (Thyagarajan). **TeNet** (Jhunjhunwala) model of IIT(M) is a viable model for India and they bring market necessities and requirements into research agenda.
- There should be clear guidelines for industry-institution/university collaborations especially in IPR sharing. There should be modalities to cover collaboration for all scales of industry – large, medium as well as small.
- Provide attractive opportunities for scientists providing consultancy services to the industry. Reduce bureaucratic hurdles preventing scientists entering consultations, in fact encourage them.
- Encourage and facilitate scientists to spawn companies and also technology transfer. In this case the US would be a better example than China or Japan.
- **Encouraging companies to invest in R&D in the universities/industry**. NMTLI is the best example of funding both industry and institutes even in high risk areas. Industries should fund research projects in the areas of their interest. Rather than pitching in just to license a developed technology, industry could fund projects at the explorative stage itself. Partnerships are built right from the beginning of research, rather than trying to license a developed technology. For example, in product development in pharma industry etc where FDA requirements are important, This will help in making the product suitable for the industry to produce in bulk quantities and to incorporate market-oriented features. Large number of "applied research projects" are of limited interest to Science. Such projects would never see the light of the day unless sufficient funding is provided via industry. Such collaborations help to increase IP wealth of India as industry would take care of protecting IPR.
- If we are going to increase number of Ph.D.s to >20,000 per year, we need to increase research fellowships and career opportunities. **Increased interactions between Academia and Industry would also lead to more job creations for highly qualified people.**

- **Encouraging internships in the industry**. Even Ph.D. scholars could become interns (like in good medical schools). Several companies are already encouraging internships.
- Industry should also encourage their employees to do Ph.D. in collaboration with academic institutions.
- There should be no doubt whatsoever on the value of **knowledge-industry and scientists interlinkages**. Their contribution to the national wealth and employment generation is significant. So, **recognition and reward of scientists must occur at levels comparable to their peers in the industry**.
- It is not the youth at high school levels who unilaterally decide the subjects of their choice but their parents play an important role. If we are able to give competitive pay packets, then we will be able to attract bright students to science careers.

In sum, we need to simply increase the number of job opportunities in science for it to attract youth, which has yet to reach a critical mass in India through some self organising systems.

Panel 5 Science as a Career

When we ask the question, What can be done to promote science as a career for the next generation, we need to introspect and accept the shortcomings of the present generation of scientists who have failed to promote science as an attractive career. This has been compounded by the failure of educational institutions to instil in students the fascination for science. As individuals and institutions, we therefore must make science challenging and satisfying to the younger generation.

Recommendations:

- Minimum facilities must be provided to take up research at the beginning of their careers wherever they are - institutes, universities, colleges. Undergraduate and post-graduate labs have been completely neglected. 99% of UGC funds goes into so-called research but labs are not upgraded. Experiments in universities and colleges are virtual and no hands-on experimentation is done. So small research projects can be administered at undergraduate level. This needs to financially supported by the government.
- Counselling of parents and good Public Relations(PR) with society is required (maybe academies can take this initiative in making public awareness that science as a career can be indeed rewarding!) since all the programs that are targeted at science students attract only those students who fail to get in to any other option such as medicine and engineering.
- Teaching faculty have to be good role models – enthusiastic and stimulating. Established and active scientists should teach at undergraduate levels and in universities – not only retiring and almost retiring scientists. Undergraduate and post-graduate teaching programmes as well as Ph.D research programs should focus on inquiring mind, creativity, learning and passion for hard work within environments which have greater flexibility, rather than only teaching and information gathering within a constraining environment. This needs a drastic surgery and not a cosmetic change.
- Greater opportunities for Ph.D.s and better good quality Ph.D.s, which are not repetitive – research problems should be original. Working environment of research labs should be improved and conducive to dissent and original research. We should find out what is the rate of drop-outs? Why do they drop out? Perhaps the bright minds are not challenged enough. Peer pressure critical for hard and honest work.
- De-link jobs from degree requirements – colleges and universities have really suffered because of degree requirements connected to jobs.
- Encourage post-doctoral work, especially those who have worked in Indian laboratories. The virtual essentiality of post-doctoral work abroad must be stopped.
- Fresh Ph.D. students must be scouted for talent and they must be given jobs.
- Gender issues must be addressed.

Plenary Session

Prof C. N. R. Rao throws the session open and asks individuals to make brief comments.

1. To begin with the pedagogy of creating teachers just doesn't exist and all this discussion will come to nought if this is not addressed of how to create fine calibre teachers.

   Secondly, the final user of research is the industry and once this is understood, we can direct our research towards this end. Take a sector by sector analysis and we can then strategise our preparedness for the coming years. Pharma industry for example though not a very fashionable sector for researchers per se, has very good industrial applications and consequently corporate laboratories in pharma are better equipped than most institute laboratories. But they cannot get Ph.D researchers in industrial microbiology, medicinal chemistry, since chemistry is not fashionable and even research follows fashion or trends. So we have to work backwards and think what kind of researchers we should be producing , and constantly think about who the end user will be and this will make us more competitive. Look at power generation as another example. As a big user industry, what demands have we created? What is our preparedness. The same can be said of the railways, roadways etc.,

   Thirdly, interaction between industry and academics will happen only if both recognise that it is mutually beneficial.

   Fourthly, competition in industry is what will create "real" scientific value and push us to innovate. What bio-transformation have we come up with in India? Have we come up with any novel organic root for any bulk intermediate agro chemical?

2. We can create more Ph.D.s but we have to create opportunities for them. National recruitment of young Ph.D.s must be instituted for colleges who are currently doing it through their governing bodies although

   government is paying the salaries. Secondly, faculty members should have full freedom to recruit post docs from abroad and there must be ways by which one can pass government obstacles. These post docs can be made to work with university faculty to revamp university system.

3. There is something more than the clichéd understanding of gender in science and we need to understand this since 50% of the population is left out and consequently the possible feedback into this process. And secondly we need to incorporate the rural areas into the mainstream academics. Thirdly the career opportunities need to be expanded and parents should be counselled for this so that their children will enter science courses. There should be more money for research especially in universities.

4. When project proposals are given to government funding agencies and are rejected without reason there is a belief that something unfair going on. So written reply with reasons should be given for all rejections and curtailments.

5. Teaching and the creation of good teachers must be addressed. Also teaching of individual subjects must be developed to make it more attractive. Secondly integration of agencies like DAE and CSIR etc need to contribute to this endeavour. Industry's role in education needs to be emphasized since they use everything that is developed by academics. There is an urgent need to form an Indian scientific cadre and a non financial, scientific auditing system that must be developed to evaluate why projects are delayed etc. Identification of vision programmes for each institutions need to be developed and gearing of research programmes to this end has to be streamlined. Incorporate travel funds into research grants to enhance the Indian presence in the international scene.

6. You senior scientists were there in the forefront when you were in your 40s(age) and now in this generation, no one in their 40s is at the forefront and that situation should be remedied.

University science education is in a pitiable state today. The context within which science is functioning today is filled with contradictions and conflicts with primary education contributing to national development, while higher education is considered as one that promotes individual development – a non-merit subsidy (like petrol). The role of council for higher education has been converted into an advisory body from a policy making and implementation body.

Chairman's Remarks

We should have this more often maybe once a year also in different parts of the country. Nothing new has emerged from this conference. I know that. What has come out is the emotion, the passion and compassion that people have for ideas and issues and things that we have to do in this country. I think that what is important to understand is the action points. Some action points have come out. Some of them will involve the political system and others the bureaucracy. We will have to work to make it happen.

Action Plan

It was clear from the discussions that there are several issues that need to be addressed, some in succession, while others simultaneously. This needs to be done, before a concrete agenda with strategy can be devised for enhancing India's competitiveness in S&T.

The action plan contains those recommendations that came up which can be developed for presentation to the government and may need to be executed at a national level. They are:

- Human Resources
- Grants and Funding
- Institutionalization
- Administration and Work Environment Facilitators

Human Resources

- Embark on a massive and **sophisticated PR campaign for changing the image of S&T** in the minds of the general public, so as to attract the best of minds into science as a career choice. The campaign should use all media and cover all sections of society throughout the country. The comprehensive strategy could include the commissioning of films and biographies of individuals and institutions, travelling exhibitions, competitions, workshops, students and parent counselling and lecture series in addition to the conventional commercials and advertisements.
- **Involve younger faculty, as well as women and other disenfranchised groups, in every facet of institutional building and science policy making** in order to create a sense of ownership and retain young scientists in the country. Establish a minimum percentage of young scientists (below 45) who need to be included on every decision making body for S&T, much as has been done for women in university boards and committees.

Grants and Funding

- Form **an autonomous agency to make funding decisions** comprised of scientists of different backgrounds and ages. Projects which are funded must routinely include funds for the recruitment of post-doctoral fellows as well as travel to international conferences to enhance international visibility of Indian science.
- Ensure **professional review of proposals** by those working in the area of specialization with which the project is concerned.
- **Identify thrust areas** such as bio-tech, or pharma or alternative sources of energy and support these with adequate resources at all levels. Increase focussed funding to table-top science to increase tinkering and innovation.
- **Fund research on issues and themes connected with women in science.** Establish and fund separate support networks for women in science and evolve organized mentoring programmes under their aegis.
- **Modernize and equip teaching laboratories in high schools** (standards 9 to 12) as well as undergraduate colleges to generate interest in science.

Institutionalization

- Establish a **Science Observatory** to study, evaluate and monitor science and scientific institutions in India and the world.
- Promote the adoption of **Open Access Archiving** at all scientific institutions to create a virtual knowledge environment which is accessible to all.
- Establish a **Mentoring Programme** through the Academies for talented rural youth and all disenfranchised and/or under-represented groups in institutions to provide active support to them in professional environments.
- Establish **undergraduate teaching programmes** at all government-funded research institutes to offer Bachelor's degrees in S&T. This will enhance the quality of students getting into post-graduate programmes. Limited non-degree programmes, such as weekend courses, summer internships, may also be offered to select undergraduates such as those offered by BASE, Planetarium, Bangalore.
- Institute the equivalent of **Bhatnagar award for undergraduate college teachers** with a minimum of 5 years experience, providing them with additional funds for innovating teaching methods. This will help revitalise undergraduate teaching.
- Establish a **summer training programmes for high school teachers** to inspire, update and share best practices in science teaching in schools.

Administration and Work Environment Facilitators

- Enforce **transparency in processes, uniformity of rules, and consistency in application** of the same under the Right to Information Act in research institutions and universities with immediate effect.
- Develop **a new policy statement on school education** which shifts the emphasis of education - syllabi, teaching and evaluation - from "teaching" to "learning", from information acquisition to learning processes, from memorizing to questioning, from repetition to analysis and creative thinking. Encourage all related government departments such as NCERT to follow these policy changes.

- **Accord Science Policy statements legal status**, develop a clear national strategy for their delivery and support them with funds for their realization based on a clear outlay to all stakeholders.
- **Encourage companies to invest in R&D in the universities or institutes.** Increase incentives for private investments in R&D. Build partnerships from the explorative stage, rather than allowing industry to license a developed technology.
- Develop an aggressive, efficient and **proactive International Patenting/ Intellectual Property system.**
- **Encourage research institute-university collaboration** through specific initiatives and mechanisms to engage with each other such as through the sharing of resources, faculty, students and offering joint programmes. Locate research labs on university campuses to develop synergy between them.

Conclusion

Earlier it has been a practise of holding national Conferences on central issues that deal with India's Future in Science and technology more frequently. The last one held was during the year. Leading scientists and policy makers in the country discussed and debated several issues related to the central theme during the meetings. This conference after a lapse of years was organised with a specific focus on India's Competitiveness and preparedness in science and technology in the coming decades- Issues challenges and strategies.

The conference was successful in more ways than one. It for the first time created a forum for the scientific community to raise issues that represented the concerns of the community at large particularly the younger faculty. The participation of the universities and the research institutions on a common platform was useful to bring into centre-stage that one is not independent of the other. The conference also placed the question of competitiveness in science and technology is intrinsically related to the culture of excellence and hence not independent of development in related fields of knowledge.

On the other hand, the conference also generated a long list of recommendations, not all of them were new in terms of strategies.

However, the issues raised at the conference can be treated as a wider canvass of concerns among the scientific community. The action plan is the articulation of the recommendations raised in a more specific form. A committee from diverse backgrounds can treat the entire document along with action plan as a draft, which needs further thought and action. In that sense, the conference can be seen as an initiative to create a wider network and draw out a longterm inter-institutional programme.

Appendix 1
Final Programme

Wednesday, 26 October 2005

09.30 am	**Registration**
10.00 am	***Welcome and Introductory Remarks*: K. Kasturirangan**
10.10 am	***Address:* V. S. Ramamurthy**
10.15 am	***Inaugural Address*: Kapil Sibal**
10.30 am	***Keynote Address*: *C. N. R. Rao***
11.00 am	**Vote of Thanks** **Tea/ Coffee**
11.30 am – 12.50 pm	Panel Discussion: I Topic: Is Indian Science Competitive? Chair: *P. Balaram* Panelists: S. Arunachalam *Performance Indicators - Citation Index/ Impact Factor* V. Sumantran *Institutionalising Competitiveness* Gangan Pratap *Place of Creativity and Innovations in Science – Setting the Trend* Sundar Sarukkai *Culture of Excellence*
12.50 - 1.30 pm	Lunch

1.30 pm - 2.50 pm	Panel Discussion: II Topic: **Science in the World and in India: Some Experiences** Chair: ***R. Narasimha*** Presentations: ***(Case Studies)*** ***Japan*** **– K. Chattopadhyay** ***China*** **– S. Arunachalam** ***India*** **- Srikanth Sastry ; G. V. Shivashankar**
2.50 pm - 4.10 pm	Panel Discussion: III Topic: **Science and Technology Institutions** Chair: ***P. Rama Rao*** Panelists: Gautam R. Desiraju ***Role of Universities in S & T Strategies*** K. VijayRaghavan ***Creating, Building and Sustaining World Class Institutions*** T. Jayaraman ***Culture of Scientific Institutions***
4.10 pm – 4.30 pm	**Tea/Coffee**
4.30 pm - 5.50 pm	Panel Discussion: IV Topic: **Collaborations and Partnerships** Chair: ***R. A. Mashelkar*** Panelists: Ashok Jhunjhunwala ***Transferring Technology to Society***

	G. Thyagarajan ***Industry Science Linkages*** Bikash Sinha ***Transnational Collaborations*** N. Balakrishnan ***IT Industry and Science***
7.30 pm	**Dinner**

Thursday, 27 October 2005

10.00 am - 10.30 am	**Tea/Coffee**
10.30 am – 11.30 am	Panel Discussion: V Topic: **Science as a Career** Chair: ***K. Kasturirangan*** Panelists: Amitabh Mukherjee ***Forward and Backward Linkages in Science Education*** S. Dattagupta ***Incentives in Science Careers*** Vineeta Bal ***Status of the Indian Scientist*** Namrata Gupta ***Challenges for Career Growth in Science***
11.30 am - 1.00 pm	Plenary Session Chair: ***C. N. R. Rao***

	Group Presentations: **Panel I** **Panel II** **Panel III** **Panel IV** **Panel V** Vote of Thanks B. K. Anitha

Appendix 2
List of Speakers, Participants & Working Groups

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