# Attracting Talented Students to Maths and Science

सत्यमेव जयते
Government of India

National Knowledge Commission

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# Foreword

We are witnessing a growing tendency among talented students to pursue studies in areas other than mathematics and basic sciences. To realize our vision of India as a knowledge society, it is essential to build a strong foundation in basic sciences by attracting a larger number of talented students to this stream. This foundation in science is needed to create the next generation of leaders and competent scientific talent and teachers. In this context, the National Knowledge Commission (NKC) considered it imperative to undertake a study to identify the causes behind the growing alienation of students from a career in pure sciences and what could be done to redress the situation.

The Eleventh Five Year Plan aptly envisages the establishment of five new Indian Institutes of Science Education and Research (IISERs), a large scale scholarship programme to encourage young talent and up-gradation of science infrastructure in higher educational institutes to promote science education in the country. However, apart from massive financial investment, a systematic and innovative approach is needed to significantly impact the choices made by talented youngsters to draw them towards basic sciences.

The NKC submitted a set of recommendations on **Attracting More Students to Maths and Science** to the Prime Minister on 2 May 2008. The recommendations have been drafted after holding widespread consultations with experts through interviews and workshops. A working group of eminent persons representing university, research institutes, NGOs, science colleges and industry was also constituted to deliberate on the issues in detail. Our proposals cover infrastructure, pedagogy, curricular and structural reforms, access enablers, branding of science careers, industry participation and outreach. This special document is being published to share and disseminate these recommendations in order to engage diverse stakeholders to generate discussion and debate. We hope that this document will help catalyze the implementation plans for the much needed change and the replication of successful science education and outreach models across the country.

Several of these recommendations have linkages with our recommendations on school and higher education, libraries, translation and open educational resources, submitted earlier to the PM. We have included highlights of the other recommendations in this volume. These suggestions should therefore be seen as part of a systematic set of knowledge initiatives for the young.

**Sam Pitroda**
Chairman
National Knowledge Commission

# Acknowledgements

I am grateful to everyone who was generous with their time and energy to participate in this project.

In particular, I would like to thank all the people who took time out of their busy schedules to grant us an opportunity to interview them and share their ideas on how we could effectively tackle the challenge of attracting more talented students to Maths and Science. In addition, I acknowledge the logistical assistance and vital organizational support provided by the following institutions for organizing workshops: Tata Institute of Fundamental Research (TIFR), Mumbai, Indian Institute of Science (IISc), Bengaluru, South Campus – Delhi University, Delhi and SN Bose Centre for Basic Sciences, Kolkata. I am grateful to all the teachers, scientists and students who actively participated in the workshops held at Delhi, Mumbai, Bengaluru and Kolkata. I would also like to acknowledge the precious ideas and suggestions by people all over the country during the course of the project.

I appreciate the time and energy spent by the members of the working group for deliberating in detail on all the issues in the area. The discussions held in the three meetings of the working group form the backbone of our recommendations to the Prime Minister.

I would like to express my sincere thanks to Dr. Ashok Ganguly and Prof. P. Balaram, Members of the Commission for their valuable suggestions during the study. I also appreciate the support and co-operation of all the other Members and Advisers of the Commission. Additionally, I express my heartfelt thanks to the staff of NKC especially Pratibha Bajaj, for providing the much needed background support to the project.

2nd May, 2008

Dr. Sujatha Ramdorai
Member, National Knowledge Commission

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# NKC Methodology

- Identification of key focus areas
- Identification of diverse stakeholders and understanding major issues in the area
- Constitution of Working Groups and organizing of workshops/seminars, extensive formal and informal consultations with concerned experts and stakeholders
- Consultation with administrative Ministries & the Planning Commission
- Discussion in NKC to finalize recommendations in the form of letter to the PM from the Chairman
- Letter to PM containing key recommendations, first steps, financial implications etc. supported by the relevant explanatory documents by NKC
- Dissemination of recommendations to state govts., civil society and other stakeholders
- Initiating the implementation of the recommendations under the aegis of the Prime Minister's Office
- Coordinating and following up implementation of proposals

**Working Groups:** Libraries, Language, Agriculture, Health Information Network, Undergraduate Education, Medical Education, Legal Education, Management Education, Engineering Education, Traditional Health Systems, More Students in Maths and Science, Open and Distance Education.

**Workshops/Seminars:** Literacy, Translation, Networks, School Education, Muslim Education, Vocational Education, Open and Distance Education, Intellectual Property Rights, Science and Technology, Agriculture, Open Education Resources.

**Surveys:** Innovation, Health Information Network, Traditional Health Systems, Entrepreneurship, More Quality Ph.Ds

# NKC Snapshot

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- Translation
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- E-governance

## Recommendations Submitted in 2007

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- More Quality Ph.Ds
- Entrepreneurship
- Agriculture
- Veterinary Education
- Enhancing Quality of Life

# Letter to the Prime Minister

2nd May, 2008

Dear Mr. Prime Minister,

As you have repeatedly emphasized, a strong foundation in the pure sciences is essential to transform India into a knowledge superpower. Unfortunately, as the economy grows, fewer students are opting for the pure sciences. This has led to a talent crunch, seriously impeding the development of the future generation of scientists and teachers. We are aware that this is a world-wide phenomenon, but countries like China and South Korea, having invested prudently in science education, are now beginning to reap rich dividends.

In this context, NKC carried out wide consultations with experts through a series of workshops and interviews. A working group of eminent persons was also constituted to consider all aspects of the problem. Based on these inputs, NKC has formulated a set of recommendations to attract and retain talented students in basic sciences which are summarized in the following paragraphs. More details are given in the accompanying note. We have chosen to reiterate some of the proposals which overlap with the views of other expert groups. We stress that this matter is extremely urgent and a rapid implementation is now crucial to effect a paradigm change in the field of science education and research in the country.

## 1. Invest in upgrading and expanding the existing infrastructure and promote sharing of available resources

University departments and leading undergraduate science colleges should be generously funded to upgrade their staff and facilities. To encourage good departments, 'Centres of excellence' should be identified with comprehensive review and evaluation procedures in place. To create a critical mass of scientists in each science stream **undergraduate seats should be increased in good institutes and undergraduate programmes should be introduced at institutes where only post graduate teaching is currently undertaken**. Innovative methods for sharing resources and faculty between institutes and universities need to be evolved. At the same time, university management at all levels should be made more professional and sensitive towards working in an academic and research environment to promote optimal utilization of resources.

## 2. Revitalize the teaching profession to attract and retain quality teachers

The working condition of teachers needs to be drastically improved. Rewards and recognition should be publicized and given at all levels. Teachers at the school and college level should be encouraged to develop innovative teaching methods. Research should be promoted in colleges by building linkages between colleges and research institutions. Academic autonomy and flexibility should be encouraged. Further, a mentoring programme for young faculty members should be started in universities and colleges. Many reserved faculty posts remain vacant in the absence of innovative or flexible appointment modes to fill these posts, creating enormous practical difficulties in teaching. There is a need to start a systematic affirmative campaign to rectify this situation. Young students who can eventually fill these posts could be selected at an early age and nurtured and trained carefully to induct them into a career in teaching.

## 3. Revamp teacher training at all levels and promote development of teaching aids to retain student attention in classrooms

A systemic change in science pedagogy from primary and high school levels is required. There is a need to launch a large scale in-service training programme for all science teachers based on the initiative undertaken by Science academies. At the undergraduate level, the present method of faculty training conducted by Staff Training Institutes/Centres should be reviewed and revamped. In addition, there is a need to provide a platform for life long skill enhancement of teachers. Teacher organizations like the Indian Association of Physics Teachers should be strengthened and financially supported so that they can become leaders in developing new teaching methodologies and make significant contributions to content and evaluation reforms.

## 4. Restructure master and graduate degrees to promote career flexibility after graduation

To bring graduate degrees in science at par with other professional streams, a four year Bachelor in Science (flexible and modular in nature) is proposed. This degree course should be aptly branded and devised so that it is significantly stronger than the regular three year programme. It should enable students aspiring for a research career to directly enter a Ph.D. programme. For others, it should provide them with measurable value additions like interdisciplinary skills, niche skills required in industry, or rigorous training in science education, science communication, etc. To ensure the success and acceptability of such programmes, the course content must be planned in consultation with diverse expert groups, and implemented at institutions with a proven track record of success. Simultaneously, the existing B.Sc. and M.Sc. courses should be reformed. The integrated five year M.Sc. programme should have the provision to be integrated with the Ph.D. programme so that the total effective time spent for a Ph.D. is reduced.

## 5. Reform the science curriculum content in line with the changing world and increase research component at all levels

There is an urgent need to reduce information load of curriculum at the higher secondary level. Courses should be made engaging and the amount of hands-on work at all levels should be increased. Books should be written by teachers who teach the subject and not by curriculum committees. Pedagogy should be modified to impart creativity and global vision training. Avenues for research should be increased at all levels.

## 6. Radical changes are required in the evaluation system to encourage scientific thinking and promote better understanding of basic science concepts

The system should move from examination based evaluation to more open assessment mechanisms. Memory, comprehension and creativity should be given equal importance in evaluation. Continuous assessment at the school level will reduce dependence on year-end examinations. To enable the modifications in the evaluation process, teachers need to be trained in new methods of evaluation.

## 7. Promote access to quality science educational material at all levels

There is a need to disseminate high quality science educational material and self learning aids in local languages to assist students from non-English medium education background. One important factor which has to be kept in mind while translating into local languages is that the technical/ scientific terms should be retained in English. This will make it easier to migrate to English medium teaching in sciences at higher level for the students. Special teaching aids need to be developed for tribal children and children from rural backgrounds to attract them towards science. Tribal schools should be equipped with teachers who are trained in pedagogical methods suited to the special needs of tribal children.

## 8. Re-brand and promote careers in basic sciences

Existing careers in sciences, namely teaching and research, should be made more attractive. There is a need to increase salaries in this field to reflect the shortage of skilled manpower and to attract students towards a career in science. Science colleges should collaborate with research institutes and industry for campus placements. More modules/courses could be designed which prepare students for employment in industry. The four year bachelor's course offered by quality institutes should dispel the myth that science bachelors are in any way less employable than graduates from other professional streams. Research institutes should collaborate with professional streams to pursue and create more opportunities. New institutes will create a demand for quality science Ph.Ds and these career opportunities need to be publicized.

## 9. Launch a massive science outreach programme aimed at students and their parents

A science popularization programme should be launched to effectively cover children across India. This programme should bring all popular science activities under one umbrella for rapid implementation and replication of successful initiatives. A large chain of science talent cells should be created and each school should be funded to open a science club. The effectiveness of mobile labs in reaching the rural students and teachers is very high. Replication of the Agastya International Foundation's mobile lab programme, with possible public private partnership mode for implementation, should be considered for various states.

## 10. Encourage industry participation in promoting sciences at all levels

As research based industries flourish in India, more and more companies will need employees qualified in basic sciences, thus creating other attractive career opportunities in science. Industry should be encouraged to sponsor students for Masters and Ph.Ds in science and also internships of longer duration in industry for post graduate students. Science undergraduates should be exposed to various applications of science in industry through seminars and popular science lectures by industry leaders. Academic institutions should develop groups at each institute which specialize in developing novel funding mechanisms involving industry and explore other possible modes of industry participation.

India has a long and rich history attesting to the high talents of Indians in science. To bring back the glory that the pure sciences once held in the minds of the students, an urgent restructuring of the entire system is needed. These recommendations are just the beginning of a systemic overhaul process, requiring great support from the government and committed individuals. The crucial ingredient for ensuring success would be an effective, mission-oriented platform for delivery. Therefore, a National Science and Mathematics Mission is proposed, the details of which are outlined in Annexure I.

NKC could provide anchor support and coordination in the launch of the Mission. We urge you to take immediate action to launch this Mission and initiate implementation of our recommendations.

Warm personal regards,

**Sam Pitroda**

Annexure 1: Concept note on National Science and Mathematics Mission

Annexure 2: Detailed Note on Attracting More Talented Students to Maths and Science

Dr. Manmohan Singh

Honourable Prime Minister of India

Copy to:

1. Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission
2. Sh. Arjun Singh, Minister for Human Resources Development
3. Sh. Kapil Sibal, Minister for Science and Technology

# Annexures

# Concept Note on National Science and Mathematics Mission

## I. The Background

It is well established that:

- Science and Mathematics teaching and research has deteriorated in India.
- Fewer students are attracted to a career in Science or Mathematics, compared to other professional subjects.
- Availability of good teachers and absence of modern pedagogy are key limiting factors in the ability of schools and Universities to make Science and Mathematics exciting.
- The new investments in institutes of higher learning in Science and Engineering are a partial response to the problems India faces in Science and Mathematics education.
- Other efforts, some of them excellent, are fragmented and restricted to few institutions.
- India's growing backwardness in Science and Mathematics will eventually retard its ability to be globally competitive and affect its economic growth and social well-being.
- Only a massive, well coordinated and well-funded national initiative, sponsored at the highest level, can begin to bring about a mindset and attitudinal change in India, towards Science and Mathematics, teaching, and research.

## II. Vision

To promote the attractiveness of Science and Mathematics as subjects and professions, essential for modern and forward looking societies, to School, University and post-graduate students; by launching an NKC Mission under the direction of the Prime Minister.

## III. Modus Operandi

- Set up a Science and Mathematics Mission made up of a core team of 40-50 brightest of the bright Indian scientists and mathematicians under the age of 45.
- Such an assembly of talent may be foregathered by a world-wide search of rising Indian stars and enlisting them to become the heart and soul of the mission. Each of them may undertake this role full-time or by devoting significant time alongside their current occupation.
- The choice of the Mission Leader is hypercritical for success. He/she should ideally be below 50 years of age and have the passion and zeal to undertake an education mission of most unique kind in recent memory.
- This Mission will only succeed if it is launched nationally and is accessible to every school, college, university and institution throughout the country.
- The Mission Chief and the task force will draw up a 5 and 10 year master plan for Science and Mathematics training and research for India.
- NKC could provide anchor support and coordination in the launch of the Mission.

# Note on Attracting More Talented Students to Maths and Science

Pure sciences form the bedrock of all applied sciences. Advancement in sciences is a necessary condition for future technological revolutions. While innovative science and scientific discoveries have the potential of enabling a quantum leap in human civilization, pursuit of sciences promotes a culture of open mindedness and rationality. India has a rich heritage in abstract thinking and has contributed to scientific discoveries since ancient times. As India ventures into the 21st century and seeks to establish itself as a knowledge superpower, it is essential that a strong foundation in science is firmly in place. This will help the nation in building excellence in technology, achieving self-reliance and in propelling economic growth and prosperity, consequently raising the living standards of all its citizens. Yet, as the economy progresses, it has become increasingly difficult to ensure a sustained input of fresh young scientists and educationists into the system. This situation has become particularly alarming in the pure sciences. Since developing competence in the basic sciences has a long incubation time, it is important that this problem be addressed with alacrity. Science and Mathematics are living subjects which grow rapidly and give rise to new areas which build on other existing areas. Therefore, they need a constant input of fresh and young talent. It is worthwhile to note that developing countries like China and South Korea have invested massively in science education in the past few decades and are reaping enormous benefits today in terms of economic development and global standing in science.

The Prime Minister has repeatedly stressed the importance of making Science a preferred discipline of study for students and has also pointed out the need for both a qualitative and quantitative expansion in the pool of science students. The strategy for the promotion of science education in the Eleventh Plan aims at (a) expanding and strengthening the Science & Technology base in our universities, and (b) promoting excellence through competitively secured funding at centers for advanced research.

In this context, NKC conducted workshops and expert interviews to analyze the issue and recommend steps to attract and retain talented students in basic sciences. A working group of eminent members representing universities, science colleges, research institutes, industry and NGOs was constituted to look into the ideas in greater detail, and this Note is a result of these deliberations. Broadly, the recommendations can be summarized as ***better infrastructure and pedagogy, curricular and structural reforms, improved access, re-branding of science careers, massive outreach and greater industry participation.*** We are glad to note that some recent UGC initiatives are in line with a few of these recommendations. We are aware that while some of the proposals below are new, various

expert groups[1] have previously made proposals which overlap in spirit and content with the others. They are reiterated here because it is felt that these proposals need fast-track implementation for effecting a change in Science Education which is critical and urgent.

## I. Resources

### Recommendation 1: Invest in upgrading and expanding the existing infrastructure and promote sharing of available resources

Science is a capital intensive subject and its pursuit requires good infrastructure, adequate resources and regular maintenance of the same. Further, better infrastructure will play a vital role in attracting students towards sciences.

**Issues:** The condition of basic infrastructure in most science colleges and universities remain largely unattractive and uninspiring to today's high school student who has an array of other attractive options while choosing his/her career. Basic infrastructure like classrooms and buildings and essential laboratory equipments deteriorate due to lack of proper maintenance. This creates a grim atmosphere for students and teachers who are interested in pursuing pure sciences.

**1.1 Basic infrastructure:** The number of seats presently available in good institutes for bachelors or integrated masters in science is limited. There is a need to expand seats at entry level in science disciplines to create a critical mass of scientists in each stream. Substantial expansion of capacity of bachelor's programme in all good institutes is required. The starting of IISERs is a step in the right direction and it is crucial that they succeed in setting an example. Care should be taken that while excellence is cultivated in them, it should not lead to their isolation.

*A continuum of institutes in quality is needed.* While there are IISERs on one end, and government science colleges on the other end, there is a need to start undergraduate courses at universities and other places which currently offer only post graduate education in sciences to complete the continuum of institutes for students with varying abilities. Select universities can offer Bachelor's honours (four year course – detailed later) with an option to directly move to Ph.D. programme after successful completion of honours.

Independent but standardized accreditation of science departments and regular evaluation of accredited institutions is necessary. Accreditation agencies should be sufficiently supported to carry out regular evaluations. This rating information will help students to take informed decisions when

[1] Higher Education in Science and Research & Development: The Challenges And The Road Ahead, INSA and IAS, 2006; Attracting Young People to Careers in Science, Office of PSA, 2005; Report on University Science Education, IAS, 1994

they choose their place of study. This will also serve to direct public funding where it is most optimally utilized.

University departments should be generously funded and upgraded with staff and facilities. To begin with, a few departments could be identified, a plan prepared for their conversion to centers of excellence and then continual monitoring of the progress could be undertaken. This task can be accomplished by either UGC or directly by MHRD. Leading undergraduate science colleges should be chosen to provide them with additional assistance and turn them into centers of excellence. Clusters of undergraduate colleges should make a *centralized* request through university for comprehensive funding.

UGC has a provision to provide grants to the universities for providing financial support to the faculty for travel or to organize seminars. This should be extended to colleges with a proven track record. In fact, a comprehensive funding mechanism needs to be in place which will cover capital as well as maintenance expenses, work related field trips for students, support to publish articles etc.

**1.2 Sharing resources:** Many valuable facilities are not optimally shared among research institutes, laboratories and universities. The funding agencies should promote the formation of centers for shared instrumentation, by facilitating a consortium approach. Full-fledged laboratories within the campuses of our universities and other educational institutions can be set up. Greater collaboration should be promoted between research institutes and universities through appropriate incentives. Further, colleges which do not have adequate infrastructure should form clusters with nearby colleges and institutes to share laboratory resources, especially expensive equipments.

**1.3 Scholarships:** The number of direct scholarships to meritorious students like KVPY (Kishore Vigyanik Protsahan Yojana) should be increased to cover a larger student population. To enlarge the pool of scientific manpower and foster research in the sciences, the Government of India has announced a programme entitled "Innovation in Science Pursuit for Inspired Research" (INSPIRE). The INSPIRE programme should be launched as soon as possible.

**1.4 Autonomy and flexibility:** *"A university is about learning that molds a lifetime, learning that transmits the heritage of the millennia, learning that shapes the future."* While efficient university administration should facilitate this, bureaucratic stranglehold and political interference vitiates the academic environment, creating a war of nerves between academicians and the administrators. Universities have to be financially accountable to the government, but the academic matters should be under the sole purview of the university bodies. At present, even academic matters like starting new innovative courses have to be approved by the state governments. These proposals do not see the light of the day even after several years. Academic autonomy is essential to contemporize

syllabus and make it more relevant. The administration at all levels should be made transparent, professional and sensitized towards working in an academic and research environment.

To facilitate teaching in universities by research scientists, supporting infrastructure should be created in universities for visiting professors. Further, University and research institute faculty members should be given the flexibility of taking sabbaticals for teaching in colleges, doing work in educational field and for popularizing science among children, teachers and communities in rural and urban areas. Appropriate checks and balances can be put in place to ensure that the organizations where the faculty members choose to work are indeed benefiting from their participation.

There is a horde of grant disbursing government departments and organizations. Researchers seeking funds for their projects have to manoeuvre across all these administrative hassles to get funds. A web portal which brings all relevant funding information together should be launched. Administrative problems and delays created by funding agencies should be done away with. Competitive process for grants should be established. Principles of e-governance should be incorporated to promote transparency in the system.

## Recommendation 2: Revitalize the teaching profession to attract and retain quality teachers

The working conditions for science teachers at all levels should be improved. Massive efforts are needed not only to make teaching an attractive profession for young science trained professionals, but also to revive the desire to teach and inspire students in existing teachers.

**Issues:** The base salary of teachers is low. Further, reward and recognition mechanisms do not exist. Basic infrastructure is inadequate and poorly maintained. In addition, systematic politicization of universities has contributed to the deteriorating environment. Overall, the morale of the teachers is severely affected. Teaching is taken up by uninspired practitioners who do not communicate the passion for doing science. Shortage of teachers in colleges results in additional burden of teaching load leaving little room for innovation in teaching. The practice of contractual teaching without appropriate remuneration has created its own problems. Access to good libraries, teaching aids etc is not available. College teachers do not get exposure to newest developments in their fields. Academic freedom and flexibility is lacking in the present rigid system.

**2.1 Rewards and recognition:** The teaching profession has been severely undermined in recent years and the working conditions of teachers needs to be drastically improved. It is essential that teachers are given due recognition for their contribution to society. Salaries need to be hiked across the board. Rewards should be instituted for good teaching based on student feedback in colleges. The rewards should be given at all levels and should be organized with sufficient publicity. Innovation

in teaching should be encouraged through appropriate incentives. The practice of instituting chairs like National Professors should be extended to school and college teachers too.

**2.2 Professional development:** School teachers should be provided with avenues to discuss new pedagogical developments. For instance, they should be encouraged to do projects in laboratories in colleges during vacation time. Colleges can be given separate funds to run such programmes. School teachers should be sufficiently incentivized to develop new experiments and activities to be used at school level.

Teaching load in colleges should be lightened to provide scope for professional development. There should be a provision of research facilities in all colleges or a system wherein interested college teachers can avail of nearby research facilities. Access to journals and internet based learning must be provided. New faculty members should be given lighter teaching load and a start up grant for research. This will enable them to establish themselves in their chosen research area. There is a need to increase academic freedom at all levels. *Academic autonomy is important in retaining teachers.* Teachers should be encouraged and empowered to try new pedagogical tools. Flexibility is important to contemporize classroom learning and make it more engaging.

**2.3 Mentoring:** A mentoring programme for young faculty members should be started in universities and colleges. Experienced faculty members can mentor junior members on issues related to starting new research projects, grant application writing etc. They can share tips on different aspects of classroom teaching, like syllabus planning, managing the classes, etc. Peer evaluation of teaching and exchange of ideas on pedagogy should be encouraged.

Many reserved faculty posts remain vacant in the absence of innovative or flexible appointment modes to fill these posts. This leads to excess strain and teaching load on the existing teachers. In addition, this has contributed to the gradual decay and death of many departments of pure sciences in colleges and universities around the country, which were once famous for their science teaching. *There is a need to start a systematic affirmative campaign to rectify this situation.* Young students who can eventually fill these posts should be selected from an early age and nurtured carefully to induct them into a career in teaching. Special mentor programmes with highly individualized attention should be an inbuilt part of this programme.

## Recommendation 3: Revamp teacher training at all levels and promote development of teaching aids to retain student attention in classrooms

A systemic change in science pedagogy from primary and high school levels is required. Teaching should be made more inquiry based. It should raise curiosity, convey the excitement of science and enable understanding of nature through experiments.

**Issues:** Unimaginative science teaching has promoted rote learning, thereby dousing the very spirit of enquiry that a study of science should nurture in young minds. Teaching is accompanied by a limited number of demonstrations and activities. Science is projected as an abstract difficult subject to its young practitioners. There is no effort on the part of the system to engage students in the process of scientific enquiry. Emphasis is not laid on thorough understanding of fundamental concepts. Instead, students are overloaded with more and more information. This is also encouraged by the current evaluation system and various competitive examination bodies.

**3.1 Teacher training:** To help teachers keep pace with recent advances in their subjects and new pedagogic tools, there is a need to launch large scale in-service training programme for all science teachers. Training teachers is necessary because at the middle school level, they are expected to teach general science courses though they might have received training in only one of the disciplines. The delivery medium should be classroom based, supported by materials based on ICT. Video-conferencing sessions can be very useful. Science academies have launched such a training programme, and this can serve as a model for other institutes.

The in-service training programme for teachers needs to be revamped. The frequency of training should be increased. Teacher training institutes should be measured on their performance based on outcomes. Every training school can be linked to nearby schools for this purpose. The performance of students can be taken as a substitute for measuring the performance of teachers associated with the training school. Apart from fundamental concepts, inquisitiveness, creativity, problem solving and research orientation should be included in teaching. At the undergraduate level, the present method of faculty training conducted by Staff Training Institutes/Centers should be reviewed and the training system with lectures alone should be done away with. There is a need to revamp the Refresher and Orientation courses conducted under the guidance of UGC. The need is to provide a platform for life long skill enhancement of teachers.

Dedicated training centers can be established at research institutes/universities for advanced level courses. A database of good teachers should be created so that they can be tapped for discussion forums, video-conferencing sessions and for live interactions with trainees. Lectures of good teachers should be recorded and made available in CDs/internet for easy accessibility. Web enabled discussion forums should be promoted. Teachers should be connected with one another so that in time, teacher organizations can become leaders in developing new teaching methodologies and make significant contributions to content and evaluation reforms. *Well established associations like Indian Association of Physics Teachers and others like the nascent Indian Association of Teachers in Biological Sciences should be strengthened by appropriate financial and other support.*

**3.2 Teaching aids:** With the advent of new technology, there is a need to develop better teaching aids to make classrooms livelier. There is an array of open source material and ICT

aided tools, which can make classroom transactions in math and science more engaging and participatory. At present, it is felt that neither the teachers nor students are fully familiar with these resources. Multi media should be appropriately used, and easily replicable hands on activities to demonstrate scientific concepts should be made part of regular teaching. The Hoshangabad Science Teaching Programme should be emulated by the training schools to enable teachers to use these concepts in their own schools. Virtual laboratories programme should be encouraged and scaled up so that schools which are in a position to benefit from such experiments have the opportunity to do so.

**3.3 Some external measures to raise quality of science teaching:**

- Good teachers can offer common courses in an institute cluster. This will enable access to good teaching for a large number of students and provide them with an option of host of electives.
- Bright young faculty should be attracted with high salaries. This will inject much needed fresh blood in our universities.
- Researchers in India and alumni in research institutes abroad should be encouraged to teach. They are best positioned to convey the excitement of science.
- Schemes that permit utilization of the skills of talented teachers and scientists, who have reached formal retirement age, will be an important step in maintaining standards in many disciplines, which have been hard hit by declining recruitments over the years.
- Universities should be given financial support to attract good teachers and researchers from institutes in India or abroad (for periods ranging from one semester to an academic year or so) to help introduce teaching in new fields.

## II. Science education in schools and colleges

### Recommendation 4: Restructure master and graduate degrees to promote career flexibility after graduation

Structural reforms in courses are needed to streamline available options and present students with multiple options. Preferences of students who intend to pursue a career in research will be different from those who want to work in industry immediately after graduation. Many students may want to pursue a more generalized science course while others may prefer a highly specialized course focused on a particular stream.

**Issues:** The present courses of study available at various colleges and universities involve repetition at each level. This affects students' interest adversely. There is a need to integrate course curriculum from senior secondary level to master level in sciences. Most of the B.Sc. courses in the country fail to provide a wider conceptual base in diverse disciplines of Science and thus severely limit "inter-disciplinary" capability of the graduating students. In the absence of extensive laboratory work, the graduates do not know how to actually do an experiment and without any self-undertaken exploratory experimental work, they also fail to learn how to ask new questions for research.

*4.1 To bring a graduate degree in science at par with other streams, a four year Bachelors in Science course is proposed.* This degree course should be aptly branded so that it gains more significance than the regular three year programme. To ensure the success and acceptability of this programme, the course content must be planned in consultation with diverse expert groups, and implemented at institutions with a proven track record of success. The first two years of this course would be common for all students. The students may choose their streams based on interest and performance after two years. If the course is offered in an institute/university where engineering courses are also offered there can be a provision of flexibility to move from B.Sc. to B.Tech. Further, a student could also choose to take a 4 year integrated B.Sc. plus B.Ed. course in colleges where such a facility is available. A *four year B.Sc. + B. Ed. Programme* is a more effective training programme than the current practice of B.Ed. after completing B.Sc. Funding of this programme should be given special attention. Universities/Science colleges must be encouraged to run such programmes. If the student does not opt for B.Ed. then she/he can either do a research project in final year or take up employment friendly modules like clinical research, statistics, etc.

The exact duration of the course need not be fixed but should be based on credits. Thus, if a bright student completes the requirement of all necessary credits a semester before, she/he could do additional advanced courses in the remaining period. Also if the place s/he is studying offers M.Sc. and Ph.D., there should be flexibility to start earning credits for the master's courses such that the total effective time spent in B.Sc. + M.Sc. is reduced, and the student can directly opt for Ph.D. at the end of the course. The government should encourage universities and IITs/IISERs/ research institutes to start a broad based undergraduate degree programme in science. Based on the course credits students acquire, the degree can be aptly named like Bachelor in Mathematics and Computer Science, Bachelor in Chemistry and Biology etc. Highly specialized courses like Biotechnology or Bioinformatics at undergraduate level should be avoided. Instead the emphasis should be on broad based knowledge of various science streams.

4.2 The three-year regular B.Sc. course should be reformed. In the first year, the programme should include courses in all major disciplines of science, so that all students learn the basics of "physical", "life" and "earth" sciences. These courses should advance the student's understanding beyond the +2 level where the focus is more on information due to limited evaluation methodology. "Deficiency" courses may need to be planned for those who have not studied Mathematics or Biology at the +2 level. In the second year, a student may select three main subjects; however, about 15-20% of credits should be earned through courses from other streams (e.g. a student of "Physics/Maths" stream may take some courses in Biological/Earth sciences and vice-versa. In the final year, the student may select one subject (Major subject) out of the three studied in the second year. Again, 15-20% credits should be obtained through courses in other streams. These should also include courses designed to improve "skills" like computer programming, statistics, instrumentation (optical/electronic) etc.

All science courses must include 30 to 40% credits in laboratory and field work (where applicable as in Earth sciences and some areas in Biological sciences) and the laboratory exercises should be planned in such a manner that students have opportunities for "hands on" training, and a certain proportion of practicals should be "open-ended" so that students can learn to be innovative/ exploratory. The "open-ended" exercises may also be in the form of "projects", which should include, besides the actual study, preparation of a formal report. Care must be exercised to ensure that the practicals do not become "rituals" or "demonstrations", and project reports do not get replicated from one batch to the next.

It is also desirable that language courses are introduced, at least from the viewpoint of presentation of data in scientific reports/papers. In addition, the students should also be encouraged to take some extra credits in courses in other faculties, like Arts, Social Sciences etc to develop a more integrative personality. To encourage communication skills, each student should be required to give at least one seminar on a current topic in the final year of B.Sc.

4.3 The integrated M.Sc. offered by many institutes should be made more flexible. The programme should offer more elective choices for students. It should be restructured so that the students have the option to pursue a part of their training outside the mother institute. This is being followed successfully in institutes like BITS Pilani. Further, a student should have the flexibility to major in a science stream and obtain a minor in engineering or technology or another science stream. The programme should have the provision to be integrated with the Ph.D. programme offered by the institute so that the effective time spent in B.Sc. + M.Sc. + Ph.D. reduces. Also the integrated M.Sc. should have a provision of exit for a student after 3 years with a B.Sc. degree. As an integrated M.Sc. course by its very nature will have a major interdisciplinary component, it should be run in institutes or universities which have the infrastructure to provide such flexibility. Students should have the option to study a wide variety of subjects before choosing their thesis topic. A cluster of institutes in the same locality can come together to present and offer such a bouquet of courses.

4.4 Premier engineering institutes should be encouraged to offer a combined master's degree in technology and sciences to lure some students to sciences. Flexibility to change streams from engineering and medicine to sciences and vice versa should be built in. Masters and doctorates in pure sciences should be open to graduate engineering and medicine students. Remedial courses can be run by premier institutes to bridge the gap in the knowledge of professional degree students. The BITS, Pilani model is worth studying in this context. Frequent interactions with students of engineering and medical streams are important to expose and enable students to contribute to interdisciplinary research. Interactions can be planned in the form of research projects, student seminars and conferences on recent advances in each discipline where participation is open to all.

## Recommendation 5: Reform the science curriculum content in line with the changing world and increase research component at all levels

There is a need to change the balance of content in favour of hands-on activities and research at all levels. Increase in experimental learning will increase student interest in science. Content development activities also need to be altered to cater to all segments of student population.

**Issues:** Firstly, the curriculum load at school level has significantly impacted the understanding of fundamental concepts. Inflexibilities in the course curriculum, lack of application oriented content and poorly designed laboratory courses have made sciences unattractive. Secondly, emerging technology has reshaped and continues to reshape every discipline rapidly. Competitive advantage will rest with those who have life-long self learning skills and humanistic grounding and not with those stuffed with most information. Globalization demands individuals who can cope with exploding and challenging landscapes of the future world. There is a need to modify the current education system to adapt to changing needs of society.

**5.1 Reduction of load:** *There is an urgent need to reduce information load of curriculum at higher secondary level. Courses should be made engaging and not very heavy. Fundamentals should be emphasized by providing more background and application related problems on each concept.*

**5.2 Content reforms:** *The amount of hands-on work at all levels should be increased.* To make sciences interesting, local environment can be made a part of learning. Students can apply principles of science to solve local problems. This can be coordinated with local science bodies. Group activities, hands-on training, student seminars, project camps in summers should be encouraged at all levels. Laboratory courses should follow a continuum. To aid learning by inquiry, more exploratory methods must be incorporated into the curriculum. A larger number of experiments, kits and multi media teaching aids should be created using, as far as possible, locally available materials with accompanying do-it-yourself books. Most textbooks at school level do not describe the details of experiments and teachers are often not sure how to do the experiments or why their experiments fail – it should be ensured that practical manuals explaining details should be made available. Details about where the requirements /kit items can be available and expected cost should be provided. Students should be encouraged to experiment in a creative, unfettered fashion. This calls for changes in the curriculum, teaching and attitude of school administrators (not viewing labs or instruments or chemicals as prized possessions, etc).

*Books should be written by teachers who teach the subject and not by curriculum committees.* A culture of writing books needs to be developed. Mass collaboration for content development should be encouraged. The government should promote Indian edition of latest books in science.

To be ready for the ever changing scientific world, we should develop and impart creativity training that is the ability to synthesize conceptually. Pedagogy should be modified to entail such training. To empower students to face future challenges imposed by globalization, global vision training should be imparted to students. Student exchange programmes should be increased as international students bring fresh perspective crucial for turning out global citizens.

**5.3 Increasing avenues for research:** As students advance in their studies, whether undergraduate or graduate, they should be frequently exposed to people who are immersed in solving serious problems in global change, energy and environment, pharmaceuticals, biology and biotechnology, finance, cryptography, and communication – again without dilution of standards. At the undergraduate level, this can be done through popular science lectures. Research institutes and universities should collaborate to launch attractive programmes for students. These *specialized courses* will help in channelling student interest towards sciences. Scientists should be incentivized for teaching. If the research institutes have adequate teaching infrastructure, some of them can run six months residential courses at their premises and offer research training in the final semester to post graduate students.

Undergraduate summer fellowships should be popularized and increased in number. The fellowship programme currently run by science academies and other research institutes should be integrated and popularized so that students have uniform access to information and opportunity to do a project at a premier institute.

A "University Innovation Fund" can be constituted to promote projects by college/ university researchers showing potential for innovation. The funding system should be intensively peer reviewed. These innovative grants should be closely monitored in terms of performance with a provision for early termination if milestones are not achieved. On the same lines, the College Science Improvement Programme can be promoted. Teachers should come together to design and fabricate new lab experiments.

## Recommendation 6: Radical changes are required in the evaluation system to encourage scientific thinking and promote better understanding of basic science concepts

**Issues:** The present evaluation system tests memory instead of comprehension. It does not promote creative thinking or problem solving. The selection processes discount originality in thought, innovative ability and passion for hands-on science. These elements are far more important for a career in research. The fun of studying science has been forgotten in the current competitive scenario where science students are focussed at solving problems which appear in various entrance examinations in the shortest possible time.

**6.1 Alternative evaluation methodologies:** ***The system should move from examination based evaluation to more open assessment mechanisms. Memory, comprehension and creativity should be given equal importance in evaluations.*** More weightage should be given to round the year hands-on activities and laboratory work. Continuous assessment at school level will reduce dependence on year end examinations. If we could develop a system where a holistic record of student performance from school to college is maintained, then this can be used as an alternative or additional input to entrance examinations for entry into various institutes after higher secondary level.

At the college level, introduction of semester system will reduce the anxiety related to year end examinations. Internal assessment should be increased and given more weight. Internal assessment should focus on experimental projects which will create demand for laboratories. This in-turn will lead to demand for better laboratory facilities and consequently improved infrastructure in all colleges. Other measures which will encourage students to go beyond rote learning are open ended examinations which test comprehension rather than memory and open book examinations focusing on problem solving and critical thinking. Group testing and field-work based testing should be used extensively.

**6.2 Enablers:** To enable the modifications of evaluation process, teachers need to be trained in new methods of evaluation. Academic calendar should be strictly adhered to. There is a need to increase the teacher to student ratio to ensure better interaction and assessment. A ratio of 1:40 should be targeted. One can look at a unified National Level testing at mid school level and after school completion to reduce load of competitive exams on students. Another important application of such testing could be to bring forth areas where teachers need to be trained.

## Recommendation 7: Promote access to quality science educational material at all levels

To attract more talented students to Maths and Science, it is essential to ensure access to quality science education to all students. There is a need to disseminate high quality educational material in local languages to assist students from non English medium education background. Educational materials should be provided to all at subsidized rates.

**Issues:** The quality of education in sciences across the country varies widely. Many meritorious students have no access to quality education. There is a large section of student population which receives school education in local languages. These students do wonderfully well in the sciences till graduate level where the medium of instruction remains vernacular. But at post graduate and higher levels because of the monopoly of English language in science education, they face serious problems. They have to put a lot more effort to understand concepts in the English language at a higher level; often making it difficult to cope with the course work.

**7.1 Study material:** The current study material available at bachelor's and post graduate levels in science is limited and does not promote or enable self learning for students. Self learning aids will increase access to quality education and hence should be promoted. Internationally available courses in different streams can be adapted for local use. Incentives for people to create such material in academia should be provided so that people are encouraged to take up such work willingly. Further, lectures of teachers reputed for their teaching should be recorded and disseminated all over the country, enabling students and teachers to have access to quality education material.

**7.2 Translation:** Language should not act as a barrier in science teaching. To bring such students to level playing ground, apart from English language lessons, there is a need to arrange speedy and widespread dissemination of basic science education materials in local languages. These courses should be designed to facilitate understanding of fundamental concepts in the local languages and also provide a bridge towards subsequent studies in the English language. Resources should be provided to translate the best science books in local languages. Internet dissemination of these translated books should be carried out. To aid conceptual understanding, science lectures in local languages can be prepared by good science teachers capable of doing so. These lectures can be recorded and distributed to libraries of all science teaching colleges and universities and made freely available on the internet. As there is an urgent need for this task to be carried, it is important that the right agencies and people be identified and networked to carry out this work in an organized and comprehensive manner. ***One important factor which has to be kept in mind while translating into local languages is that the technical terms/scientific terms should be kept in English.*** This will make it easier to migrate to English medium teaching in sciences at higher level for students.

**7.3 Special needs of Tribal children:** Early childhood education is very important as the brain develops the fastest up till six years of age. In this context, special teaching aids need to be developed for tribal children as they are not exposed to modern technology like rest of the children. Motivation for learning has to be created by providing exposure to scientific developments. Tribal schools should be equipped with teachers who are trained in pedagogical methods suited to special needs of tribal kids. They should be well versed in local tribal dialect. Science subjects should be taught in local language till mid-school level. However, the teacher should explain fundamental concepts in tribal dialect to ensure sound conceptual understanding. Tribal dialect can be used for evaluation purposes too at lower levels. Nutritional requirements of tribal children should be taken care off. Migration is a major problem which hinders education of tribal children. Hostel facilities should be provided for older students to ensure continuity in learning.

## III. Career opportunities, outreach and industry participation

### Recommendation 8: Re-brand and promote careers in basic sciences

The prime reason that students opt for professional courses is the perception that there are no

attractive career opportunities in sciences. There is an urgent need on the part of all science teaching colleges, universities and institutes to better brand the careers in science and to spread awareness of increasing career opportunities in basic sciences.

**Issues:** Financial unattractiveness at all levels is a major reason for the downfall of interest in science. The two main occupations associated with pure sciences are teaching and research. Both careers no longer carry the respect and recognition in society as they used to. The financial attractiveness of jobs in other streams pulls students away from sciences. Parental and peer pressure de-motivates even interested students.

**8.1 Current careers:** Existing careers in sciences, namely teaching and research, should be made more attractive by providing better emoluments, security of tenure, academic freedom and facilities. Joint appointments within the country and appointment of eminent scientists in such areas from other countries under long term visiting professorships should be looked into. Ph.Ds need to be restructured to ensure better stipends for longer duration and secured post docs. It is vital that all such recommendations of appointments and salary structures have a visible component of accountability in their implementation.

8.2 Some other suggestions to attract students to careers in sciences:

- Information about job opportunities for individuals with a master or doctorate qualification in pure sciences should be made available on a portal. New opportunities in emerging fields like financial mathematics etc should be appropriately marketed. Companies working in these fields should be invited to deliver talks in science colleges.
- Science colleges should collaborate with research institutes and industry for campus placements. Career cells need to be established. Close interaction with industry and research institutes is needed to project type, expertise level and amount of manpower.
- Additional training at bachelor's level has already been suggested for increased employability. More modules/courses could be designed which prepare students for employment in industry. Students should have the choice to take such courses while pursuing bachelors. The 4 year bachelor's course offered by good institutes will dispel the myth that science bachelors are in any way less employable than graduates from other professional streams. The ability of life long learning should be instilled in students. This should be marketed well to attract companies to employ science background students.
- New opportunities in science streams need to be developed. Research institutes should collaborate with professional streams to pursue and create more opportunities. Research in emerging areas should be systematically developed. Research activities in research laboratories and universities need to be massively increased. Government should provide all possible incentives to encourage research and development in every sector of the economy.

- Large research groups should be developed. These groups should focus on taking an idea from basic research to market ready application. Such groups can be partially funded by industry. These groups should look at problems which affect a large section of society and devise plan to come up with solutions. Young researchers should be recruited in such initiatives. These research groups should be headed by a well known scientist who is capable of attracting young doctorates.
- New institutes will create a demand for Ph.Ds. A study on shortage of skilled manpower in science should be commissioned by DST. There is a need to increase salaries in this field to reflect the shortage of skilled manpower. More students will be attracted to pursue basic sciences if they realize that the rewards in scientific profession are not controlled by fixed pay scales but show an upward trend as a reflection of the scarcity of talent in the field.

**8.3 Trained technicians:** Shortage of trained technicians for science laboratories has resulted in poor maintenance of laboratories across universities, colleges and institutes. Appropriate vocational courses may be designed and introduced in areas that can provide direct employment. This may require a good analysis of local industrial and other requirements. Some general examples are: i) Bio-Medical Laboratory Techniques; ii) Bio-informatics; iii) Computer Applications; iv) Laboratory Techniques (for Physics/Chemistry labs) etc. These courses need to be so designed that the students may be ready for gainful employment. These courses can also be offered to students who are still pursuing their B.Sc. as additional courses.

**8.4 Mentoring programme:** A structured programme for mentoring students in science should be introduced. It was felt that the students in lower classes in different schools across the country are intimidated by their science and math teachers because of the teacher's attitude towards the students or the teacher's gap in knowledge. As a result, students feel inhibited in asking questions. This in turn leads to the development of a complex, which is detrimental for academic progress. On the other hand, if good students of higher classes, at least 4 years older, come forward to assist the younger students, the latter would benefit by peer learning as this is associated with a sense of ease and freedom. The Young Instructors programme of Agastya International Foundation is a model which could be replicated in this context at all levels. This programme will instil confidence in senior students and lead to their holistic development too.

The programme can be started at first in schools where a few hours every week are kept aside for close contacts like informal tutorials between groups of seniors and juniors. Such a tutorial programme should be expanded later to cover students' questions on careers. School teachers can be trained to act as career counselors. Students' doubts regarding uncertainty in pursuing a career in science should be effectively dealt with.

## Recommendation 9: Launch a massive science outreach programme aimed at students and their parents in particular

The declining interest in sciences is a wider phenomenon and needs to be addressed comprehensively. Large scale science popularization programmes are needed to re-establish the passion that science once generated. The objectives of science programmes should include:

- To spark curiosity and imbibe scientific way of thinking
- To spread awareness about latest discoveries and their impact on society
- To discuss issues related to adverse effects of scientific developments
- To promote science as a medium of socio-economic development
- To glorify careers in science - The media, parents and students should be sensitized to the various career options and job situations available to students coming out of science streams. This would encourage more students to science and reverse the alarming trend of lack of interest in basic sciences.

**9.1 A large science popularization programme:** A science popularization programme should be launched to cover 250 + million children effectively across India. This programme should include all the objectives mentioned above. Apart from money, it will require committed people with vision and capacity towards execution. The importance of this programme necessitates consideration of out-of-the box organization and service delivery alternatives. This programme should bring all popular science activities under one umbrella for effective implementation and replication of successful initiatives.

**9.2 Science cells, centers and mobile labs:** A large chain of science talent cells should be created. Each school should be funded to open a science club. A network of good teachers, laboratory facilities and reading resources connecting like-minded students in every town/city is needed. The school science clubs can be then networked to the local centers of science. The local science centers should have experimental models to demonstrate basic science concepts. The centres would be equipped with personnel to explain and answer questions of students. Provision should be made to facilitate visits to this science centre by connected science cells. The Centre would act as an "anchor" for the rest of the state's science activities and mobile lab programmes, which would be dispersed across rural taluks. In general, the various state governments should facilitate building of more engaging and interactive science parks and museums for learning science outdoors.

To tap talent from rural India, special efforts are needed. Science programmes for rural children should be started – book grants, computer grants etc can be given apart from direct scholarship. ***The effectiveness of mobile science labs in reaching rural students is very high and the programme should be replicated across India.*** The Agastya International Foundation's mobile lab programme should be studied in this regard. A suitable public private partnership mode can be worked out

where a company can sponsor the capital cost of the mobile labs in return for some minimal publicity like logo, etc on the van. The Government under its Sarva Shiksha Abhiyan can sponsor the operating costs of mobile labs to reach rural schools. Such a model is running successfully in many districts of Karnataka. Apart from mobile science labs like in vans, such labs can also be put in coaches of passenger trains run in the interior regions of the country by Indian Railways and in buses of State Transport Corporations.

Mobile science libraries similar to mobile science laboratories can also be promoted. These should have child friendly volumes on interesting topics including science fiction. Alternatively, children's/ public libraries should be opened all over the country by the government. These could lend out books to schools and other registered institutions in bulk, say 100 or more books at a time for, say a month – this could be useful since expecting each school to be able to identify and purchase suitable books is unreasonable. Good books could be identified for each state and purchased in bulk for/by the public libraries.

**9.3 Local science programmes:** While we need to build a very strong machinery to promote sciences, science research institutes, science academies and local science organizations and scientists (role models) in their individual capacity should participate in this task of nation building. Science should be used as a means to engage students in a variety of extra curricular activities. Science exhibitions, science competitions and popular science lectures can be organized by local science organizations/teachers' association/group of schools to promote application of what students learn in their environment. Different ventures to encourage and popularize science, such as mobile vans, science centers, interactive exhibits, workshops and activity centers for children should be supported financially.

Journals and popular science magazines can play an important role in spreading the scientific temper among citizens especially among college going students. The country needs many more child friendly science magazines, especially in local languages. TV programmes like 'Turning Point' and 'Quest' that were hugely popular and provided a platform (turning point) for asking 'scientific questions' for children and adults alike should be promoted.

Science programmes focused at non-metro students should be launched. Local languages should be used in science dissemination. Scientists should communicate more to masses through the media. A national science portal, promoting science contests etc can be created. The Government can mandate outreach programmes as part of grant applications.

The Children Science Congress organized by the Department of Science and Technology is a laudable effort. Its scale should be expanded and more schools should be included. Information should be

made available, and should be readily accessible at all high schools and junior colleges about careers in Science, and this should be publicized among the teachers at these levels. Programmes like Vigyan Manthan Yatra of the Madhya Pradesh Government, Science centre proposed by Assam Government, Science city concept of Tamil Nadu and Gujarat Government etc are also good efforts and should be replicated across India wherever possible.

## Recommendation 10: Encourage industry participation in promoting sciences at all levels

Industry participation is important in making sciences popular. As research based industries flourish in India, more and more companies will need employees qualified in basic sciences. This will visibly provide more attractive career options.

**Issues:** The current industry participation in science education is very low. It needs to be increased manifold. Companies need to realize that their investment in science education is a long term investment for their own benefit.

10.1 Select companies, which employ research scientists, can come forward to offer jobs to Ph.D. students post completion of their doctoral degree. Ideally this commitment should be made at the time when a prospective Ph.D. student is deciding about joining the degree programme. Some industries are already doing this in Computer Science. Industry can sponsor Ph.Ds for students after setting some certain minimum criteria or it can hire students at master's level and provide scholarships to pursue Ph.D. in chosen fields.

10.2 Industry internships of longer duration for post graduate students should be encouraged for students who intend to pursue a career in industry. This will enable them to learn work place skills as well as expose them to latest technologies and research methodologies. Industry should also devise methods to optimally utilize the student's stay in their workplace.

10.3 At bachelor's level, employable skills like computer training, communication skills etc should be included in the curriculum. Undergraduates should be exposed to industry problems through seminars and popular science lectures by industry leaders. This will engage students in scientific issues and motivate them to solve some of these problems in the future.

10.4 Teaching aids: Industry can participate in creating study material which can be directly used by students. Self learning should be promoted at all levels. The massive efforts required in translating science study material into local languages can be undertaken by companies which have some expertize in this field.

10.5 Industry sponsorships for science fairs, laboratories, science centers and mobile labs should be sought. A mutually beneficial partnership can be worked out between universities, NGOs and industries to promote science popularization programmes. Industry should be encouraged to invest in basic infrastructure and maintaining them in universities and also in providing scholarships to deserving students. Universities should interact with industry in terms of needs, employability skills, etc. In India, a few technology companies have started exploring possible symbiotic relationships with universities in recent years. This needs to be structured and massively encouraged. Further, if the academia desires industry co-operation, it has to move away from examination orientation. Inter-disciplinary approach is needed to handle partnership projects. This should be facilitated.

10.6 Academic institutions should develop groups at each institute which specialize in developing novel funding mechanisms involving industry. The academia on its part should run courses to train industry personnel. It should take up industry sponsored projects for effective interaction. Academic institutes should invite industry to visit institutes and demonstrate facilities to create confidence in the industry people. Universities can create interface bodies for effective research work. Such collaborative work will generate funds for universities too.

*In short, restructuring of the entire system is needed to bring back the glory that the basic sciences once held in the minds of the students. Many of our recommendations on infrastructure, autonomy, access, evaluation and pedagogy have synergies with NKC recommendations on higher education, school education, libraries, translation and open educational resources. We have highlighted the most important things which have to be in place to work the system around. We believe that the implementation of all these recommendations in a coordinated fashion will charge the system to act as a magnet to attract students towards basic sciences.*

Annexure 2.1

# Note on National Science and Mathematics Mission

## I. Background

While all these recommendations are necessary to reform science education in the country, the crucial ingredient for ensuring success is people with vision, ability and commitment to execute, supported by an effective, mission-oriented and formalized organizational platform for implementation and to achieve the goals and objectives of science education and popularization. Progress in the field of science in India has been on the decline. Countries like China and South Korea which were behind India in scientific standing have marched ahead. Developed countries are also facing similar onslaught due to shortage of skilled manpower in this field.

The rapid progress of science and growth of new scientific areas in recent years has resulted in many of these areas being unrepresented in the country. This has been largely caused by the decrease in the number of people who pursue the sciences, and we have already lost decades of scientific progress. It is high time that we put our act together and launch a nationwide science movement to regain our lost glory. The pressures and challenges we face call for bold, innovative and decisive action. The penalty for NOT acting is falling back irreversibly, condemning millions of lives to mediocrity, and ceding the potential for the country's transformation and greatness in the 21st century.

Therefore, a National Science and Mathematics Mission is proposed. The Mission will consolidate, streamline and coordinate all the activities which are now being performed as piecemeal and isolated ventures by different agencies. The Mission will be directly responsible for achieving the goals and objectives of reforming science education. It will be an autonomous and unifying body providing leadership, direction and inspiration to all organizations working in the field of science education, research and popularization. It will launch a nationwide campaign to attain its objective of a paradigm shift in the field of science, which would include both strategic long-term and specific goal-oriented projects.

## II. Vision

To promote excellence in the field of science education and research and to popularize science and the scientific spirit in society

## III. Constitution

The choice of the Mission Leader is hypercritical for success. The Mission should be headed by a person (under 50 years, preferably younger) with demonstrated interest in and knowledge of science education,

and the management and entrepreneurial skills necessary to build and inspire a nationwide science movement. The Mission head will enjoy the freedom to run and operate the Mission similar to the freedom and responsibilities enjoyed by the CEO of any major organization. A core group of 40-50 or more young people, of whom the majority will be under 45 years, with knowledge, management skill and deep interest in changing the science education landscape of the country will lead the effort to catalyze and disseminate science education. These Change Leaders of Science will be selected on a nationwide basis with appropriate representation of scientists, school, college and university teachers, science NGOs, innovators, industry leaders and science popularization organizations. The Mission Leader and the team will then draw up a 10 year master plan for Science and Mathematics training and research for India.

Above all, the Mission must demonstrate passion, innovation and the capacity to inspire. It should be run as an independent and autonomous organization with clearly defined goals and milestones, and must have the freedom to act decisively to achieve its goals.

## IV. Objectives

The proposed Mission will strive to achieve the following objectives:

- To launch and manage a massive science outreach programme and to support and coordinate science popularization activities of all member organizations
- To coordinate among various governments/government departments and set up science centers and mobile labs across the country
- To create and manage a Science Corps of teachers, students, educators, scientists, retirees and others who are interested in working with/reaching out to deprived children and teachers across the country
- To create a platform where curriculum designers at all levels interact to integrate course curriculum from higher secondary to post graduate level in science
- To promote creation and disbursal of quality science educational materials and teaching aids
- To facilitate development of courses in line with recent development in science and emerging employment opportunities
- To promote research opportunities in science and science education for teachers and students in schools and colleges
- To ensure access to information related to science education, research and career
- To ensure and monitor up-gradation of infrastructure in universities and colleges
- To plan, execute and supervize a nationwide in-service science teacher training programme
- To organize academia industry meets and discover novel ways of participation in science related activities by industry

To ensure the success of this country-wide programme the Mission must operate as a 10 year programme. It can delegate most of its responsibilities to concerned organizations with a systematic process of review at the end of 10 years. NKC could provide anchor support and coordination in the launch of the Mission.

# Consultations

## I. Workshops on Maths and Science were held at:

1. Tata Institute of Fundamental Research
   Mumbai
   16 August, 2007
2. Indian Institute of Science,
   Bangalore
   23 August, 2007
3. South Campus, Delhi University
   New Delhi
   10 September, 2007
4. SN Bose Centre for Basic Sciences
   Kolkata
   5 October, 2007

## II. The following is the list of experts who were interviewed in their individual capacity:

1. Prof. Manindra Agarwal
   Department of Computer Science
   IIT Kanpur
2. Prof. K.R. Parthasarthy
   Theoretical Statistics and
   Mathematics Unit
   ISI Delhi
3. Prof. S. Ramaswamy
   Director, Ramanujan Research Centre
   for Higher Mathematics
   Alagappa University
4. Prof. V. Vinay
   Chief Technology Officer
   Geodesic Information Limited
5. Prof. T.V. Ramakrishnan
   Department of Physics
   BHU
6. Prof. Shiva Prasad
   Director, IndoFrench Centre and
   Department of Physics, IIT Bombay
7. Prof. N. Mukunda
   Former President
   IAS and Centre for High Energy
   Physics, IISc
8. Prof. Alladi Sitaram
   Statistics and Mathematics Unit,
   ISI Bangalore
9. Prof. C.S. Yogananda
   Sri Jayachamarajendra College of
   Engineering
10. Prof. S.G. Dani
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# Additional Extracts

## School Education

- Substantially increased public spending is required for both elementary and secondary education.
- Urban planning and local planning must explicitly incorporate the physical requirements for schooling, including provisions for play grounds and other school facilities.
- The norms for central government disbursal to states of Sarva Shiksha Abhiyan (SSA) funds and other central schemes for school education are too rigid and must be made more flexible.
- There should be greater flexibility in disbursing funds down to the school level and a greater degree of autonomy of local level management in the use of funds.
- There should be transparent, norm-based and straightforward procedures for the recognition of private schools, as well as for the disbursement of aid from the government to self-financing schools and the ability of school management to raise resources from other sources.
- The collection and speedy dissemination of accurate and current data on schooling must be made a priority. It is necessary to create a complete database on schools and school-age children so as to track the actual coverage and quality of schooling at different levels, and to make it widely available in a timely manner.
- There is a multiplicity of management structures and government departments in the administration of school education. This creates confusion, unnecessary replication and possibly inconsistent strategies across different schools. There must be greater co-ordination between different departments of government on school education policy, even while ensuring more autonomy to the local community in matters of day-to-day management of schools.
- The system of school inspection needs to be revamped and revitalized in most states, with a greater role for local stakeholders.
- The training of school teachers is extremely inadequate and also poorly managed. Pre-service training needs to be improved and regulated, while systems for in-service training require expansion and major reform in all states.
- Curriculum reform remains an important issue in almost all schools. School education must be made more relevant to the lives of children. There is need to move away from rote-learning to understanding concepts, good comprehension and communication skills and learning how to access knowledge independently.
- New technologies, especially but not only ICT, should be used as much as possible to reduce costs, enable more effective use of resources, and provide wider exposure to students and teachers.

## Higher Education

- Create many more universities
- Change the system of regulation for higher education
- Increase public spending and diversify sources of financing
- Establish 50 national universities
- Reform existing universities
- Restructure undergraduate colleges
- Promote enhanced quality
- Ensure access for all deserving students
- Affirmative action

## Engineering Education

- Reforming the regulatory framework
- Improving the governance of institutions
- Attracting and retaining faculty
- Curriculum reform
- Integrating sciences and engineering education
- Encouraging research
- Industry-academia interaction
- Improve access to all
- Mentoring by elite institutes of other educational institutes

## Vocational Training

- Increase the flexibility of VET within the mainstream education system through the following steps
    i. Aspects of general education (such as numeracy skills) should be retained in VET as far as possible, to enable students to return to mainstream education at a later stage.
    ii. Courses in training institutes and polytechnics should have distinct tracks for students of different educational attainments.
    iii. Entry requirements for certain trades should reflect the requirement of the trade (as appropriate, for instance the entry requirement of Class X could be relaxed to Class VIII in some cases). Students should be permitted multiple entry and exit options in the vocational education stream.
    iv. Links should be established between the vocational education stream and school education as well as higher education.
    v. Courses devoted to certain skills training at the primary and secondary level should be introduced in all schools.

vi. Vocational training should be made available in various literacy and adult education schemes.
vii. Schemes for lifelong skill up-gradation, through short training programmes, should be introduced.
viii. There should be a provision for generating a cadre of multi-skilled persons.

- Quantify and monitor the impact of vocational education
- Increase resource allocation to vocational education
- Expand capacity through innovative delivery models
- Enhance the training options available for the unorganized and informal sector
- Ensure a robust regulatory and accreditation framework
- Ensure proper certification
- Undertake a re-branding exercise

## Translation

- Provide impetus for developing translation as an industry
- Establish a store-house of information on all aspects of translation involving Indian languages
- Promote printed as well as virtual publication of translation studies
- Create and maintain various tools for translation and encourage machine translation
- Provide quality training and education for translators
- Translate pedagogic materials at all levels specifically in the natural and social sciences
- Project Indian languages and literatures through high-quality translation
- Set up a national web portal on translation
- Organize annual national conferences on translation
- Promote book launches, festivals, fellowships and prizes for translation.
- Set up a National Mission on Translation for this purpose.

## Libraries

- Set up a National Commission on Libraries
- Prepare a National Census of all Libraries
- Revamp Library Information Science (LIS) Education, Training and Research facilities
- Re-assess staffing of libraries
- Set up a Central Library Fund
- Modernize library management, encourage greater community participation in library management
- Promote Information and Communication Technology (ICT) applications in all libraries
- Facilitate donation and maintenance of private collections
- Encourage Public Private Partnerships in LIS development

## Open Educational Resources

Our success in the knowledge economy hinges to a large extent on upgrading quality and enhancing access to education. One of the cost effective ways of achieving this would be to stimulate the development and dissemination of quality Open Access (OA) materials and Open Educational Resources (OER) through broadband internet connectivity:

- Support the production of quality content by a select set of institutions by launching a 'National E-Content and Curriculum Initiative'.
- Develop a network enabled infrastructure to facilitate access to online multimedia educational resources through broadband internet connectivity
- Undertake faculty development and teacher training programmes to develop pedagogic skills using new educational technologies

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