oscillation parameters. Unambiguous proof of neutrino oscillations needs to be obtained by observing regeneration of neutrino species rather than just depletion of spectra. Other questions remain. For example, is CP violated in the leptonic sector? This may help explain the baryon asymmetry in the universe. Are neutrinos Dirac or Majorana particles? Is there room for a sterile neutrino? What is the origin of the neutrino (and perhaps other fermion) masses? What role does a massive neutrino play in cosmology?

Recall that the neutrino is a *neutral* fermion, i.e. it is possible that it is its own antiparticle. Such particles are called Majorana particles. All other known fermions (quarks and charged leptons such as electrons) are Dirac particles, as they have a non-zero charge which is opposite for the corresponding anti-particle. The mass term that can be written in a Lagrangian that defines a massive neutrino will be different for a Dirac and Majorana particle. In particular, having a Majorana mass term allows for the possibility of neutrino-less double beta decay. This is not possible with a Dirac neutrino. Furthermore, the mixing matrix for Majorana particles will have more CP-violating phases. Finally, the Majorana mass matrix allows, through the see-saw mechanism, a natural framework to explain why the neutrinos have such a small mass, by invoking a large mass-scale. Such an access to very high-scale physics (near what is known as the grand unification scale) through the measurement of a small neutrino mass, is what makes the Majorana possibility an exciting one. This explains the great interest in looking for neutrino-less double beta decay.

Clearly, the implications of existing results in neutrino physics extend beyond particle physics, all the way from geophysics to cosmology. Many experiments around the world, including possibly an India-based detector, will try, over the next decade or more, to pin down the precise values of the oscillation parameters. This may help gain a better theoretical understanding of neutrino masses and mixings, and of the fundamental nature of this particle.

1. Eguchi, K. *et al.*, hep-ex/0212021, *Phys. Rev. Lett.*, 2003, **90**, 021802.
2. Ahmed, S. N. *et al.*, nucl-ex/0309004, submitted to *Phys. Rev. Lett.*
3. Ahmed, S. N. *et al.*, nucl-ex/0204008, *Phys. Rev. Lett.*, 2002, **89**, 011301; the results of this paper have been discussed in the *Current Science* Research News article: Ananthanarayan, B. and Singh, R. K., *Curr. Sci.*, 2002, **83**, 553, physics/0208096.
4. Bethe, H. A., *Phys. Rev.*, 1939, **55**, 436.
5. Bahcall, J. N., Pinsonneault, M. H. and Basu, S., astro-Physics/0010346, *Astrophys. J.*, 2001, **555**, 990.
6. Pontecorvo, B., *Sov. Phys. JETP*, 1958, **7**, 172; Pontecorvo, B. M., *Sov. Phys. JETP*, 1968, **26**, 984.
7. Raghavan, R. S. *et al.*, *Phys. Rev. Lett.*, 1998, **80**, 635.

D. Indumathi is in the Institute of Mathematical Sciences, Chennai 600 113, India
e-mail: indu@imsc.res.in

OPINION

Digital and information divides: Initiatives for change

Kailash N. Khattri

I wish to submit a couple of notions for discussion by the readership. These briefly are:

- We could effectively use the digital and information technology revolution in education and science and technological research to realize our dormant potential in these areas to a fuller extent, and
- Provide open access to empirical data on the Internet to promote capturing a larger proportion of the mind-resources nationally and globally leading to the generation of creative and innovative knowledge efficiently.

Today we often hear of digital divide afflicting particularly the developing nations. This refers to the computer education of the youth. We have to recognize that related to the digital divide there is also another divide – the information divide. We are in the information age. The driving elixir of progress is information, be it education, creative knowledge or innovation.

Back in the fifties, Prime Minister Nehru in a visionary move, established a series of laboratories and educational institutions as incubators for producing resources required for the real progress of the nation. True, a lot has been achieved by the nation. Today perhaps we have the largest force of scientists and technologists in the world. But can it not be said that we could do better in terms of our contribution to the 'new knowledge'? If so let the areas where improvements are needed be identified and efforts be made accordingly.

The curse of the digital and information divides is not only afflicting the realm of the education of the youth but it appears to be equally serious with some of the generation that is at the helm of affairs dealing with the management of our nation's science, technology and education policies and programs.

People make investments in science so as to better understand the workings of nature and to take advantage of the same in improving human life. Historically the progress of science has occurred in two ways. First, like in the evolution of species there are scientific revolutions[1] fuelled by new ideas or discoveries that disturb the equilibrium or the existing paradigms. During the equilibrium periods science hibernates just exploring within the ruling paradigms. Most of the time it just produces a replication of what was largely known or done earlier. The other avenue of revolution is via the progress of scientific tools[2]. The advent of computers and the Internet no doubt has provided new and powerful tools to science, as indeed they have also opened up the opportunity for tapping of the mind resour-

ces needed for the first type of breakthrough, i.e. creative ideas.

Students of creativity have noted several aspects that are catalytic in providing environments where originality flourishes and promote the creative phenomenon. Among these may be counted effective communication, diverse stimuli, self-initiated activity, and serendipity. Hence there is a global effort to nurse environments that promote igniting of creative sparks and great ideas that seem to bolt out of the blue. This apart, tapping the largest share of available brain forest that is India should never be underestimated.

The process of accessing brainpower from all over the world has become a matter of competition among nations and industries, which has been stimulated, with the advent of Internet. The Internet allows access to brains where they are without transporting them physically. This opportunity of overcoming communication hurdles has so successfully been taken advantage of by the information industry and in turn, has been captured by the India's IT talent. Something similar could easily be achieved in the realm of education, science and technology as well.

I am reminded of an educational experience in this connection. I joined a Yahoo group named 'Physics Zone' at the instance of a young computer-Internet savvy scientist. This group constitutes perhaps a hundred participants from all over the world. Communications among the group are posted to all the members who accordingly respond. I recently received a question from a student in Africa about the use of resistivity meters. There were several erudite responses to his question, all complimentary in nature, and some even posted detailed papers that covered the matter and much more. What excited me most is the interest the Internet provided to the student to come forward and participate with his queries with the world out there making his educational experience so much the richer. In my experience of teaching in India I found our students to be rather quiet and shy (?) of asking questions. Thus they miss an essential ingredient of the learning process that keeps circumscribing their intellectual activities even in their later lives. The sight of original papers being read paper after paper at conferences without any questions from the audience is perhaps reflective of this gap in the learning process. Could it be also hampering the intensity and the quality of our science and technology? Perhaps it is a psychological factor of treating a question or ignorance with one's capabilities that holds our students back. If so, this could easily be overcome on the Internet where one is faceless and can ask the so-called stupidest of the questions without hesitation. Could similar opportunities not be set up at Indian institutions of learning?

As the Internet has opened up possibilities of boundary-less initiatives on the intellectual front, it offers efficient means of providing all the elements mentioned above for a virtual creative work space. Cannot the barriers that spring from formatted or boxed form of functioning imposed by antiquated styles, which are setting back progress of science in India, be torn down with its help?

Can the great success of the model adopted by the information industry in going to the most competitive pool of human resources wherever that exists (for example in India) not be tried in the realm of scientific and technological and educational activities, be it fundamental research or oil exploration, steel making or innovative teaching, etc.?

An efficient means of finding innovative and effective solutions is to pose the problem to be solved to the world at large with the incentive that the best solution finder will be adequately rewarded, without creating a large body of 'captive' employees, who invariably age and become stale – a curse of time. Such a model will also be promoting 'catalysis of ideas, confidence building, credibility, creating perception and capturing mind share'. Of course a balance needs to be attained in providing regular employment and outsourcing of work (which may be done on a parallel basis very economically).

The government has taken praiseworthy initiatives in setting up important and expensive facilities for conducting modern science in many areas. However, it remains in many cases to introduce modern management techniques so that the fruits from such efforts start arriving with speed as well. As an example, the DST has installed a set of modern seismographs in India and they have been functioning and gathering data for the last several years. However, the research papers from India based on this data have been very few so far. Hardly any Ph D thesis has been produced. We have to ask why? And try to remove hurdles in the way of utilization such a great dataset for research and human resource development. There may be a need to motivate scientists and students to look at other similar data. And perhaps a way could be to make the data available at the click of a mouse on the internet so that students, physicists, mathematicians, signal processing experts, seismologists, engineers, geophysicists, geologists or any interested person can have a go at them, not only in India but worldwide. A co-lateral strategy could be to promote funding of research based on such datasets.

It is worth noting that taking advantage of IT opportunity the worldwide network of seismographic stations has put their seismograms on the Internet, which can be freely downloaded by all interested persons. Could similar opportunities not be created by the educationists and research scientists of the country to both, their's as well as the nation's great advantage?

Another matter that can use with advantage the modern communication resources is the overseeing and management of research activities and programmes. Currently the research advisement is conducted via research advisory committees in research institutes or through project advisory committees in government funded projects. This can be made immensely more effective and useful to researchers and institutions as well, if co-laterally, websites are established where all the relevant research programmes are posted together with regular progress reports on them. Visitors to the site can learn and review the programmes and progress reports and post their comments, critiques and suggestions on the site. This could open up, as noted above, the tap of the nationwide and worldwide mind-resources with little cost and provide inputs in an open and interactively dynamic environment.

Could this also not be an effective way of putting forth what an organization really stands for, where it is heading – thus providing a means of transparency and accountability to the nation at large as well?

1. Kuhn, T., *The Structure of Scientific Revolutions*, The University of Chicago Press, Chicago, 1970.
2. Gallison, P., *Image and Logic*, The University of Chicago Press, Chicago, 1997.

Kailash N. Khattri is in the 100 Rajendra Nagar, Dehradun 248 001, India
e-mail: knkhattri@hotmail.com