Perspectives on India's mathematical landscape

A brainstorming panel discussion on the state of mathematics education and research in India was held at the Indian Institute of Science, Bangalore, on 3 July 2010. The panel consisted of R. Narasimha (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore), M. S. Raghunathan (Tata Institute of Fundamental Research, Mumbai), R. L. Karandikar (Chennai Mathematical Institute, Chennai), D. Singh (University of Delhi, South Campus, Delhi), S. A. Shirali (Community Math Centre, Rishi Valley School, Madanapalle), G. Misra (Indian Institute of Science, Bangalore) and R. Ramachandran (*Frontline*). Ramachandran also mediated the discussion. The discussion brought to light the history of Indian mathematics, state of mathematics education and research in the country, the problems afflicting mathematics education at the school and undergraduate (UG) level, and some possible solutions to these.

Tracing the historical engagement of India with mathematics, Narasimha pointed out that a succinct and insightful summary had been provided by Hermann Weyl, who wrote in 1928: 'Occidental mathematics has in past centuries broken away from the Greek view and followed a course which seems to have originated in India [and was] transmitted, with additions, to us by the Arabs; in it the concept of number appears as logically prior to the concepts of geometry' (Preface to *The Theory of Groups and Quantum Mechanics*). Thus, in 16th century Europe if a was a length, a^2 was an area and a^3 a volume; in geometry-centric thinking a^4 had no simple interpretation. But two centuries earlier Madhava in number-centric India was writing down infinite series for trigonometric functions – with no qualms about arbitrarily high powers of the argument. India's engagement with mathematics followed a trajectory that went: extreme numbers → new numeral system → computational revolution → function tables → finite differences → second order interpolation → *bījagaṇita*/algebra → finite-difference (and other) equations → infinite series → Riemann sums → integrals, calculus – a trajectory vastly different from one that the West took. Following the 17th century introduction of what he called 'barbarous' algebra by Descartes, however, mathematics grew spectacularly in Europe, and played a key role in the scientific and industrial revolutions that swept it. In the 19th century an India in decline encountered a virtually 'new' European mathematics that it could not even recognize. And, provoked and pushed by people like Raja Rammohan Roy and Thomas Macaulay, India embraced the new science, an act accompanied by what Narasimha called a total collapse of classical Indic epistemology.

So the 20th century was marked by a growing number of Indians who pursued modern mathematics with distinction. But the most dramatic historical event was the brief and brilliant career of Ramanujan, who produced extraordinary results of contemporary interest in the West, without the benefit of exposure to western method (he did not know what a proof was, said his Cambridge mentor and collaborator, G. H. Hardy). Narasimha argued that the 'mystery' of Ramanujan's 'method' (– he claimed to have one) actually consisted of the old classical Indic pramāṇas of observation (pratyakṣa) and inference (anumāna) – the same ones that had inspired science in India for two millennia or more. The difference was that for Ramanujan 'observation' was provided by his own numerical, i.e. calculational experiments, whose 'raw data' fill his notebooks with numbers and algebraic forms.

But one feature of Indian mathematics that stands out in the second half of the 20th century is its total disengagement from computers as well as from computing science of the kind pioneered by Alan Turing. For a culture that started a computational revolution 1500 years ago, this disengagement from one of the most powerful set of hard and soft scientific tools ever devised by man appeared most singular to Narasimha.

S. Mukhopadhyay was the first to get international credit in the West. Two mathematical societies, namely Calcutta Mathematical Society and the Indian Mathematics Club (now known as the Indian Mathematical Society) were created before Ramanujan's work became popular. These two societies have played a significant role in the development of mathematics. The French were the leaders in pure mathematics and the Indians started to follow the West under the British rule.

There are two approaches to mathematics: pure and applied. Karandikar talked about the applications of mathematics in other fields. Mathematics has been widely applied in finance in the last decade and in economics in the past two decades. The interplay between finance and mathematics had come down with the crash on Wall Street, but has begun to regain its strength. The interplay between mathematics and economics is deep and has helped to bring the applications of mathematics to the notice of a large audience. Although mathematics in finance and financial engineering may be viewed as hype by some, it has drawn attention to mathematics among the wider public. Mathematics now finds use in genetics; bioinformatics is the result of the coming together of mathematics and biology. With the help of computer science, coding has been improved and is applied in areas such as neurosciences and cryptology. The Indian Institutes of science offer programmes with both biology and mathematics to promote interdisciplinarity.

Raghunathan drew attention to the current scene in mathematical research in India. There are a few institutions where good mathematics research is being carried out but unfortunately the quality of general research output is not as high as it should be. This can be gauged from the fact that if the work of the Fields medallists in the last 50 years or more is looked at, there are only a few in India who can fully grasp it. Most Indians have not yet ventured into these areas or even in closely related topics. Sound scholarship in mainstream mathematics has to be encouraged, only then will the general quality of research improve.

The state of UG education is in shambles and many of the courses offered do not challenge the talented students. Having a chain of new institutions is not the only solution; the teaching standards must also improve, said Raghunathan. The State Governments have to be made aware about the applications of mathematics for them to release more funds. On the bright side, the collaboration of mathematics with physics has increased like never before.

Ramachandran presented an analysis of the regional surveys on the reading abilities of children, their mathematical ability, and also the choice of mathematics as a subject conducted by the 2009 Annual Status of Education Report (ASER) and by the India Science Report (2005) of the Indian National Science Academy (INSA), through the National Council of Applied Economic Research (NCAER). An important finding of the ASER survey is that large swaths of the country still have very low levels of numeracy. This is an important issue to be tackled because despite the National Literacy Mission this is so. Interest in a subject is largely determined by the quality of teaching, and the proportion of students satisfied with teaching of mathematics decrease as one proceeded to higher classes. The quality of mathematics teaching, as found in the surveys, decreases in higher classes. This has a direct correlation to the dwindling number of students preferring to take up mathematics in College.

According to the India Science and Technology Report 2008, said Ramachandran, the percentage of students appearing in mathematics examinations in States such as Maharashtra, Uttar Pradesh, Bihar, Madhya Pradesh and Punjab is low. There is a noticeable sudden drop in the students' performance in high school mathematics in Tamil Nadu in the last couple of years. The state of Indian mathematical research is not too good either. A decline in the share of mathematics in the total number of national publications has been observed from 1997 to 2007, though the absolute number of research papers published has increased (SCOPUS 2007). There has been an increase in the number of journals in which mathematical papers appear. Among 17,051 Indian students obtaining science and engineering doctorates in the US during 1985–2005, a meagre 575 were from mathematics.

Singh dealt with the issues concerning UG education in mathematics. Most of the students pursuing life sciences do not know the basics of mathematics. Reading habits need to be nurtured among students. Creators of knowledge must also act as disseminators. Teaching methods and syllabi have to be reformed, and technology (which allows for video lecturing and conferencing) should be utilized. Interdisciplinarity has to become a part of the UG education and students need to be exposed to the applications of mathematics. Singh gave an example of a summer school, 'Inviting all young minds' conducted at the Delhi Public School, New Delhi. The programme successfully inculcated in the participants the ability to see the creative use of mathematics, for instance in computer simulation.

Shirali presented the status of mathematics in schools by way of a SWOT (strengths, weaknesses, opportunities and threats) analysis. The strengths are: skills in manipulative algebra and analytical thinking, and an interest in solving puzzles and crosswords; the realization of the value of education; respect for mathematics; and availability of adequate funds. However, the education system is slow in its progress and any proposed change is met with opposition by the bureaucracy. There is a high urban–rural divide, and the education system is further widening this gap. There is lack of good centres of learning and good libraries, and poor reading habits among teachers; also, the demand for books and journals is low. Teachers tend to stick to the prescribed syllabus, showing no willingness to learn new concepts and problems, and this attitude gets transferred to students. After independence in 1947, the country invested a large amount of money in higher education and research, but not enough in primary education and teacher training. Shirali emphasized the need for a journal devoted to high-school mathematics, where teachers as well as students can bring forth their ideas. This could be developed along the lines of *The Mathematical Gazette*.

New opportunities have opened up and these could be exploited for improving education in mathematics. These include developments in technology, interest in open source software, increased availability of inexpensive, well-written books, and funds from the Government and the private sector. But there are a number of threats to the system; these include the coaching centre culture, bureaucracy, poor working conditions for teachers, a shortage of trained teachers, and a misplaced enthusiasm for Vedic mathematics. Shirali ended his talk on a positive note saying that there are possibilities of enhancing incentive schemes like the KVPY and awarding more scholarships; increased funding to existing libraries; opening new libraries and resource centres in remote areas; starting active training schemes for teachers; and most important, starting a national school-level mathematics journal.

The meeting ended with Misra announcing that the President of India will inaugurate the International Congress of Mathematicians being held in India in August, 2010. He then described some of the activities planned for the event.

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