1. Mathematics education in India – An overview

R. Ramanujam

Institute of Mathematical Sciences, Chennai
jam@imsc.res.in

Introduction

The spirit of modernity and development in nations is reflected in their investment in children's education in general. If science education is often termed as societal investment in the envisioned future, education in the "high roads of mathematics" perhaps constitutes their hope for the as-yet unvisioned future. Presidents and Prime Ministers remind their people that science and mathematics education need to equip the nation's youth to meet the challenges of the 'new economy'. Modern nations see value in building a mathematically literate society and hope for a strong mathematical elite that can shape the knowledge economy of the 21^{st} century. At the same time, mathematical proficiency is universally considered hard to achieve.

India, with its strong mathematical traditions, may be expected by the world to produce excellence in mathematics. But this may be an unreasonable expectation, since India is grappling with problems of endemic poverty, and even universalising education is a challenge. Yet, despite adversity, India has managed to produce mathematicians like Ramanujan and Harish-Chandra. All this adds up to an intriguing picture.

In contrast to the expectations of the global elite, one should consider the hopes and aspirations of the Indian people themselves. In a population that is largely poor (by any standards), education is seen as the key instrument to break out of poverty. As many adult education programmes in India demonstrated, the non-literate or neo-literate poor see the ability to 'calculate', to 'estimate' and to 'predict' as essential life-skills that education must (and hopefully does) impart, skills whose natural home in the school curriculum is mathematics. Once again, what one perceives is a sense of disappointment that school education does not impart such skills. In a *public hearing* in 2006 when a curriculum group met members of the general public, a grocer bitterly complained that he could never find educated young recruits who could *calculate* when stocks would need to be replenished and by how much.

What then characterizes mathematics education in India? We suggest that it is this mix, of severe systemic challenges, but yet a growing young population approaching them with a sense of hope, in a land of many innovations and initiatives, a system operating rather chaotically. In this article, we attempt to give a bird's eye-view of the vast landscape of mathematics education in India.

Systemic Challenges

The landscape of mathematics education in India calls for a very broad vision to encompass and comprehend. It is not only a matter of scale and magnitude in numbers of children and teachers that constitute the system, but also messy but democratic modes of functioning in which there are pulls from many social and political aspirants of society. We want every child to learn mathematics and enjoy it; the reality of achieving this with millions of children and teachers by democratic means provides a major systemic challenge. Before we look at how this affects mathematics education specifically, we need an understanding of the vast system it operates in.

The law called Right of Children to Free and Compulsory Education Act (abbreviated as Right to Education or RTE Act) came into force in India as recently as April 1, 2010. It guarantees 8 years of elementary education to every child in the age group 6-14 in an age appropriate classroom in the vicinity of his/her neighbourhood. This implies the right of every Indian child to quality mathematics education as well.

The subcontinent

Education in India is provided and controlled by three levels: the central government in Delhi, the state governments and local sources (largely private). It is regulated by both the centre and the states; this has crucial implications for designing and implementing curricula and pedagogic practices, policies for hiring and training teachers, monitoring schools, for setting standards and ensuring them, procedures for certification and ensuring overall systemic health. The states are responsible for these functions, the centre being largely regulatory but helping with funding. This at once enables many decentralized efforts as well as challenges attempts at national or centralized education reform.

The linguistic and cultural diversity of the Indian subcontinent accommodates a range of voices and approaches, and offers multiple ways of approaching mathematical experience. Many states in India are themselves geographically as large as some European nations and often larger in population. Education within these states is administered in further divisions of educational districts, but there is little decentralization within the state. Curricular and pedagogic processes are not locally shaped, and the state educational authority is as remote as the central government from the viewpoint of a school. While this enables curricular homogeneity, it tends to stifle local pedagogic ingenuity.

Structure

India's education system is structured by developmental stages from pre-primary to post-graduate level as shown in Figure 1. Elementary education (primary and upper primary) is managed separately from secondary (including higher secondary) education. Undergraduate education is typically for three years, and 4-5 years for professional degrees. Universities are regulated centrally but managed within the state, with a system of affiliated colleges providing undergraduate education.

The Ministry of Human Resource Development governs the overall Indian education system, with each State government having its own Education Ministry, and a Central Advisory Board on Education providing the platform for exchanges between the centre and states (as well as between states). In all 43 Boards of School Education operate in the country and they are the ones that formulate syllabi, train teachers and offer certification.

For school education, the National Council of Educational Research and Training

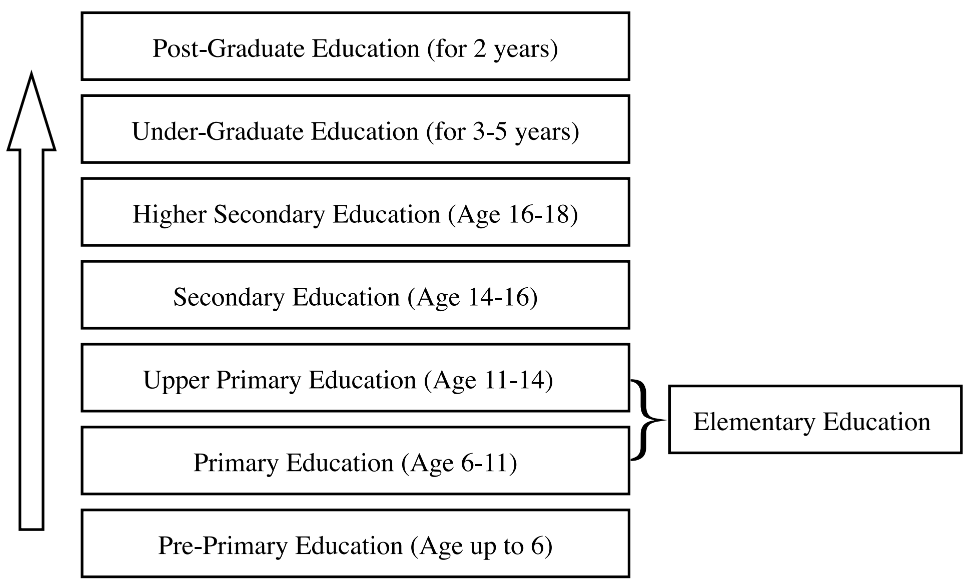

Figure 1: Levels of Education in the Indian System

(NCERT) is the apex body for curriculum related matters, but except for the Central Board of Secondary Education for which it designs curricula, its role is largely advisory vis a vis the other Boards of education. At the University level, every University formulates its own curricula but the University Grants Commission regulates their functioning.

There is a vibrant Open University system as well as the National Institute of Open Schooling that seek to provide access to education cutting across potential barriers formed by these structures.

Large numbers

Even a cursory look at the numbers shows how daunting implementation can be, and we take up only data from primary education for discussion.[1]

	Total	Number in rural areas
Number of children (ages 6-11)	134 (boys - 69, girls - 65)	108
Number of schools	1.28	0.8
Number of teachers*	5.8	4.5

*May include teachers also teaching in the upper primary grades

Table 1: Numbers related to primary education in India (in millions as of 2009)

The numbers already reveal a picture of a large education system, largely rural and millions of missing girls. That the government is the main provider of education for the population becomes clear when we note that, of the 1.28 million schools, 1.03 million are government-run. Of these, 0.8 million have classes only for the primary stage and 0.23 million have classes up to upper primary sections. The average number of teachers in a primary-only school is 2.98 and 6.96 for a school that has classes 1 to 8. The average pupil to teacher ratio is 36 for primary-only schools and 33 for schools with primary and upper primary levels.

The Quality Dimension

Why should it matter for teaching arithmetic and basic algebra whether the number of schools is one thousand or one million? After some threshold value of n (possibly 3 or 4), perhaps teaching mathematics to 10^m children is the same as 10^n children for any $m > n$. To some extent, this is the viewpoint embedded in much of educational administration in India, and mathematics educators are deeply aware of the injury such attitudes can bring to children's education.

According to some Indian scholars, the central challenge of Indian education is dealing with

[1] All data in this section are from the Final Report 2008-09 of Sarva Shiksha Abhyan, the Education for All project of the Government of India. They are intended to be indicative of the current scenario.

the metaphorical triangle of *quantity, quality* and *equality*. The state sector in education is beset by major shortage and uneven spread of resources, as witnessed by the large percentage of single classroom schools, as high as 38 percent in a rather large populous state like Andhra Pradesh. Such extreme shortage of resources presents a tremendous quality constraint. Much worse, and especially relevant to mathematics education, is lack of qualified and committed teachers. No system can rise above the quality of its teachers, and content knowledge of mathematics is crucial for mathematics education. Set against this is the data that nearly 43 percent of teachers in India in elementary education do not possess a college degree of any kind, let alone in mathematics.

Indian society is division-riven and this provides a great challenge for quality and equality in education. Mathematics being a compulsory subject of study, access to quality mathematics education is every child's right. On the other hand, there is considerable research (though not specific to mathematics classrooms) to suggest that teacher preconceptions, bias and behaviour, causes discrimination against children from the groups with low socio-economic status, the so-called "Scheduled Castes" (SC) and "Scheduled Tribes" (ST).

We have spoken of the missing millions among girls. The girls who do come to school are subject to social discrimination as well. In rural areas preconceptions such as mathematics being "unnecessary" for girls can be observed even among teachers. Despite the better performance of girls in Board examinations than boys in recent years, the stereotype that boys are better at mathematics than girls is seen to persist.

The social context of Indian education is reflected in the sharp disparities between different social and economic groups, which are seen in school enrolment and completion rates. Thus, girls belonging to SC and ST communities among the rural and urban poor and the disadvantaged sections of religious and other ethnic minorities are educationally most vulnerable, and data confirm this.

Set against such a bleak picture is also hope, arising from several wellsprings of activity:

1. Against all odds and amidst extreme diversity, we find children who take to mathematics and teachers committed to mathematics education. Statistically small, they still make up a large number given the size of the Indian population.

2. While social barriers are a great challenge, the confidence and energy released by overcoming them is very positive. Mathematics, being the discipline of thought without great need for texts, laboratories and other paraphernalia, and being the discipline that greatly inspires confidence and self-esteem, becomes then an instrument to break out of adversity for children from these disadvantaged sections, especially girls.

3. Southern India has seen how the growth of computing and Information Technol-

ogy industry offers a sense of hope to people, and perhaps due to the popular perceptions of computing, to a surge in interest in mathematics education. Among this is a noticeable increase in the participation, in mathematics learning, of girls and children from underprivileged sections.

4. The educational reform process initiated in the last decade has seen a churning across the country within school mathematics, in terms of attitudes and approaches to it. While it is too early to tell whether these efforts will lead to radical shifts, the trend is positive.
5. Lastly, the use of technology, only recently coming in as a factor, may help India solve some of the systemic problems discussed above.

Reforms

While mathematics was seen to be an essential part of any curriculum from early on, perspectives differed. The Zakir Husain committee in 1937 saw it in relation to work. The National Policy on Education in 1986 saw it as a "vehicle to train a child to think, reason, analyze and to articulate logically." However, the shape of mathematics education has remained largely the same over the last 50 years. In response to global curricular processes in India too there has been considerable curricular acceleration in school Mathematics. For instance, calculus which was only taught in college three decades ago is taught now at the higher secondary level. On the other hand projective geometry has almost entirely disappeared from the school. At the undergraduate level, the core curriculum remains much the same, though the influence of computer science and other modern disciplines can be seen in the course mix on offer.

In all this, one strain that has been persistent is the experience of anxiety and failure associated with Mathematics. Excessive use of procedure and the pressure of Board examinations and entrance examinations for access to prestigious institutions have created a culture of highly competitive preparation among the urban elite, and this has taken a toll on meaningful mathematics. On the other hand, in almost all Boards if there are specific disciplines that record failures, mathematics is principal among them. It is often referred to as the 'killer' subject and studies showed that a large number of children were failing or dropping out before completing elementary school because they could not cope with the demands of the curriculum.

Over the end of the last century, a perception that mathematics education was increasingly becoming burdensome and ineffective had gathered momentum. The Report 'Learning Without Burden' (Ministry of Human Resource and development, 1993) had pointed out that children were in fact not 'dropping out' but were being 'pushed out', owing to the 'burden of non-comprehension', as a result of an irrelevant curriculum, distanced from the lives of the majority, and often rendered 'boring and uninteresting' by outdated teaching strategies. This shift from conventional 'deficit theories', which attribute children's inability to learn to some 'deficit' in their mental abilities or their home background, led to a critical review of the curriculum and the traditional teaching learning process based on rote memorisation of facts.

The National Curriculum Framework (henceforth "NCF 2005") responded to this and guided the development of new curricula and textbooks based on how children actively construct knowledge, rooted in social and cultural practices (National Council for Educational Research and Training [NCERT], 2005). The NCF 2005 position paper on the teaching of mathematics (NCERT, 2006a) begins by stating that the primary goal of mathematics education is the "mathematization of the child's thought processes" and the development of the "inner resources of the growing child." It goes on to argue for a "shift from content to process", recommending a multiplicity of approaches, to liberate school mathematics from the "tyranny of the one right answer obtained by applying the one algorithm that has been taught". It emphasized the need for processes such as "formal problem solving, use of heuristics, estimation and approximation, optimization, use of patterns, visualization, representation, reasoning and proof, making connections, and mathematical communication".

Subsequent to this, many Boards of education in the states undertook a curricular review exercise and the last few years have witnessed a churning. While the lofty goals articulated above may be hard to achieve, there have been some significant shifts visible in textbooks and pedagogic processes, especially in elementary education. However, secondary education, weighed down by the shadow of Board examinations, remains hard to reform.

The end-of-school Board examinations remain landmark events in the lives of children, and as passports to economic mobility, they critically inform attitudes to education. These exams cast long shadows and inordinately influence classroom assessment. In fact, the traditional pattern of examinations in mathematics have been a matter of serious concern and have not only intimidated children but have often dissuaded more creative teachers too, since their classroom efforts to encourage sense making tend to get obliterated by the focus on procedural questions devoid of meaning and contextual relevance.

In this context, the pressures of a democratic society on Board examination results have to be acknowledged as well. When single subject failures tended to be high in mathematics, the pressure to set exams that fail fewer pupils became strong. This has led to a situation where pass rates have increased among those who appear for Board exams, but many who give up, drop out much earlier. This also means that high achievement in many of these exams may not attest to high competence or mastery of the subject either.

One solution to this has been attempted in many parts of the world, that of streaming students into Basic Mathematics and Advanced Mathematics, with the former constituting mathematical literacy that the state considers essential for its citizens, and the latter dictated by disciplinary objectives. But this is problematic in India, since they can become yet another form of social discrimination, with the latter course simply not being offered in many schools which children from poorer sections attend. Indeed, this was the experience in many Indian states in which such streaming existed till the 1960's. In a society that is already deeply riven by many social schisms, the possibility that the rights of disadvantaged children to quality education in mathematics might be subverted presents a major problem.

The reforms we have spoken of have come about because outside the formal system the country has had a range of educational initiatives, largely experimental and small scale but nevertheless carried out by passionately committed educationists. The valuable lessons got from such work contributed significantly to the national reform process. Such work is still visible in India, across geographic regions, from primary schools to university education.

Higher stages

We have spoken at length about elementary education. The situation is similar in secondary and tertiary education, but the fact that India has the third largest higher education system in the world (after China and the USA) suggests that there is a great deal of mathematics around as well.

According to India 2009 Reference Annual (Ministry of Information and Broadcasting, 2009), India has 20 universities run by the Central Government and 215 run by States. In addition there are 100 autonomous institutions deemed-to-be universities that do not get their funding directly from Governments. Nearly 16000 colleges are affiliated to these universities, among them 1800 exclusively for women.

India is also home to some institutions where world class research in mathematics is carried out. A strong group of Indian mathematicians have been contributing to the development of many areas of mathematics. The legendary genius Srinivasa Ramanujan has inspired generations of young Indians towards taking up mathematics as a calling.

India boasts of institutions of technology and medicine that have been globally acclaimed for their standard of undergraduate education. These, and the boom in Information Technology industry (and its generation of jobs) in the last two decades, have led to a greater emphasis on mathematical training, and the nation seeks to expand a pool of scientifically equipped manpower.

This creates a situation in India where higher education in mathematics forms a very sharp pyramid. A few elite institutions offer excellent opportunities for mathematics research, and a small number for mathematics education as a part of technology or engineering education, or in some instances, management studies. However, among the large number of universities and a vast number of affiliated colleges, which provide the bulk of tertiary mathematics education, there is an overall rigidity in curriculum, pedagogy and modes of assessment that make mathematics education often ineffective, and this affects the prospects of building a strong pool of mathematics teachers for the future. Small innovative initiatives towards constructing a meaningful interactive pedagogy at the undergraduate level give hope for solving this problem on a larger scale in the future.

The major challenge

If one were asked to isolate and point to one single challenge as the most important among the plethora of problems that we have mentioned, it would have to be that of *creating a pool of good mathematics teachers in the required numbers*. At the elementary stage, the numbers exist, but not with the required understanding of mathematics or attitudes towards mathematics or comprehension of how children learn (or fail to learn) mathematics. The social inequalities in India and the resource-poor rural schools call for greater competence on the part of teachers than richer, more democratic societies. This calls for new modes of teacher professional development that are yet to be formulated.

At higher stages, the numbers are daunting. The existing pool of teachers is woefully inadequate for meeting the requirements, especially with universalisation of school education becoming a conceivable reality within a generation. With the numbers, the problem of rigour and depth in mathematical knowledge and practice becomes more acute. Devising systemic measures to achieve quality in teacher preparation is perhaps the most urgent need in the Indian mathematics scenario today.

Research

An important agenda for mathematics education in India is research in mathematics education. University departments, while undertaking research in education, by their typical structure, tend to attract largely people who are neither mathematically trained nor thus inclined. Further, the idea of research providing solutions to curricular conundrums or pedagogic trauma remains outside the framework of decision making in education. This is not to belittle the tremendous contributions made by governmental as well as non-governmental initiatives towards reform that have been characterised by innovation and commitment. However, these do not rest on a scaffolding of research and rigorous critique as yet. The system needs to build a way of actively pursuing research on several fronts towards well formulated questions and use the answers to influence policy. It should be noted here that India provides a large enough arena, with tremendous diversity, to even allow a self-contained universe for analysis and research, and international influences can only add to this richness.

The agenda for such research includes not only internalist critique from the discipline of mathematics and its pedagogy and practices. Indian society and its cultural and work-based practices also offer avenues for mathematical explorations that a pedagogue could incorporate into a toolkit. However, a body of research needs to be built to make realistic use of such possibilities.

Last words

This heady mix can be summarized, perhaps a bit crudely, as follows:

1. The challenge of providing quality mathematics education for all at school level is immense, and the country has some way to traverse to achieve this.
2. The need for a large body of teachers with expertise in mathematics and training in pedagogy is acute.
3. The Government is the central player in Indian education, but it is not monolithic either.
4. On the other hand, India's diversity has given rise to a range of initiatives, some small, some large, including some from the Government.

We have spoken of problems endemic to the Indian mathematics education system, but many of them are not unlike problems encountered in mathematics education in other societies and nations. The immense size and diversity of the Indian subcontinent, low levels of resources and an almost ungovernable polity complicate, but the sense of hope that prevails suggests that India may yet solve these problems, that force us to take a hard look at mathematics not only in terms of curricula (in diversity), pedagogy (in widely varied milieu) but in social context as well.

One thing is for sure: when India manages to provide quality mathematics education for all, mathematics education as a discipline would have new insights and new formulations to work with.

References

Ministry of Human Resource and Development (1986). *National Policy on Education*. New Delhi: MHRD. Retrieved April 9, 2012 from University Grants Commission Website: http://www.ugc.ac.in/policy/npe86.html

Ministry of Human Resource and Development (1993). *Learning without burden: Report of the National Advisory committee appointed by the Ministry of Human*

Resource Development. New Delhi: MHRD.
National Council of Educational Research and Training (2005). *National curriculum framework*. New Delhi: NCERT.
National Council of Educational Research and Training (2006a). *National focus group on teaching of mathematics report*. New Delhi: NCERT.
National Council of Educational Research and Training (2006b). *National focus group on aims of education*. New Delhi: NCERT.
National Board of Higher Mathematics (n.d.). Retrieved April 9, 2012 from :http://www.nbhm.dae.gov.in/about.html
University Grants Commission (n.d). Model Curriculum.Retrieved April 9, 2012 from University Grants Commission Website: http://www.ugc.ac.in/policy/modelcurr.html
University Grants Commission (2011). 11th plan guidelines. Retrieved April 9, 2012 from http://www.ugc.ac.in/financialsupport/xiplan/guideline.html