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DEVELOPMENT OF MATHEMATICAL SCIENCES IN INDIA DURING THE TWENTIETH CENTURY*

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Mathematical sciences include pure mathematics, applied mathematic, statistics, mathematical operations research, computational mathematics, mathematical physics, mathematical economics, etc. In this article, the roles of various individuals, professional societies, UGC, DAE, DST, NBHM, CSIR, etc. in the development of pure and applied mathematics in India in the 20th century are examined. Some related developments in mathematics education are also considered. These developments are considered in the context of development of science and technology in the country. The various recommendations of the National Committee on Mathematics Education and Research and the NBHM Conference on Development of Mathematics in India are considered. It is suggested that mathematics in India can have a bright future if these recommendations are faithfully implemented. Some suggestions for an indepth study of the history of mathematical sciences in the modern period are also made. Special attention is given to the developments of the last ten years.

1. EXPONENTIAL GROWTH OF MATHEMATICAL SCIENCES

In the twentieth century, mathematical sciences, along with other branches of science and technology, have been growing at an exponential rate with a doubling period of about ten years. This implies that if we had one unit of mathematical sciences in 1900, we have today about 250 units of mathematical sciences and by the end of the present century, we are likely to have one thousand units of mathematical sciences. 99.9 per cent of the Mathematical Sciences in the year 2000 AD would have been developed in the twentieth century itself.

In India, the explosion in the growth of mathematical sciences has not been less spectacular, whatever criterion is adopted, i.e. whether we consider the number of students studying mathematics in our schools, colleges and university departments or the number of PhD scholars or the number of PhD theses produced per year or the number of advanced books written or the number of mathematical scientists of Indian origin working in other parts of the world or even the funds spent on mathematics education and research. In every case, the numbers have been multiplied by a factor of 50 to 500. Of course, in some cases where nothing existed in 1900, the multiplying factor has been infinity!

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* An updated version of an invited paper presented at the Indian National Science Academy Seminar on Science, Technology and Social Change 1900-1980 on 22 February 1985 held in Calcutta.

Thus the number of PhD theses in mathmatics has grown as follows[1]*:

1901-1910	1911-1920	1921-1930	1931-1940	1941-1950
1	1	11	14	39
1951-1960	1961-1970	1971-1980		
176	817	1526		

In addition, in the decade 1971-1980, 327 theses were produced in disciplines of Statistics (155), Operations Research (25) and Computer Mathematics, including Programming (47). It is expected that in 1981-1990, we shall have more than 3500 PhD theses and in the next decade, the number of PhD theses may exceed 5000.

The Indian Science Congress Association published a survey of fifty years (1912-1962) of mathematics in India. It gave references to 823 papers classified as follows:

Algebra (47), Theory of Numbers (59), Geometry (75), Infinite Series (170), Differential and Integral Equations (65), Fluid Mechanics (162), Elasticity (100), Relativity (100), Miscellanous (45), Total 823.

In 1972, it published a survey of the progress made in one decade only (1963-1972) and this survey lists 1477 papers as follows:

Algebra (26), Theory of Numbers (160), Geometry (200), Functional Analysis (60), Interpolatory Problems (13), Summability (75), Topology (85), Matrices (25), Fluid Mechanics (140), Elasticity (175), Relativity (275), Total 1477.

Though neither survey claimed to be exhaustive, yet 1477 papers in 10 years as compared with 823 papers in 50 years gives some idea of the exponential growth of mathematics[2].

In the first three decades of this century, only one university, viz. Calcutta University, was producting PhD theses (out of 14 theses produced, 13 came from Calcutta University and one from Allahabad University). Today, about a hundred universities are producing PhD's in mathematics. In fact, during the first twenty-five years of its existence, IIT, Kanpur has produced about three times the number of theses produced by the entire country in the first five decades of this century.

While in the first two decades, Indian share of world research in Mathematical Sciences was negligible, roughly of the order of 0.1 per cent, today Indian contribution is 3-4 per cent and in some fields like probability and mathematical statistics, it is as high as 12-15 per cent. Of course, 20-30 per cent of the research is contributed by Indian mathematical scientists settled abroad.

*These numbers refer to Notes given in Section 9.

Again we have to remember that considering the population of our country and the great traditions in mathematics we had in the past, our contribution to world research should be 15-20 per cent. Moreover, while our contribution in quantitative terms is respectable, yet in qualitative terms and in terms of the impact it produces on world mathematics, our contribution is far from satisfactory.

2. Role of Professional Societies

It is no mere coincidence that the first set of PhD theses was produced in Calcutta University, since it had a great deal to do with the founding of the Calcutta Mathematical Society and its nurture and development by its dynamic leader, Sir Asutosh Mukherjee, who was its president during 1908-1928.

The next set of theses came from Madras University and this again had to do a great deal with the founding of the Indian Mathematical Society in 1907 with its headquarters at Madras. In its early stages, the Indian Mathematical Society was nurtured by a band of highly enthusiastic persons who were however themselves not researchers. Its journal consisted mainly of problems posed and solutions given to these problems. This created an excellent climate for research, but it delayed the PhD programme considerably. In fact, serious research in Madras University started only when Prof. Vaidyanathswamy[4] joined the reorganised mathematics research department of Madras University in 1927.

In this period, of course, Madras produced Ramanujan[3], the self-taught mathematical genius. He was greatly encouraged by the office-bearers of the Indian Mathematical Society who could not understand his researches because they were themselves not research workers. Ramanujan also found an outlet for his creative energies by publishing some of his early papers in the *Journal of the Indian Mathematical Society*.

The credit for starting research in North India goes to Prof. Ganesh Prasad[3] who brought some inspiration for it from Calcutta University where he had served as Professor of Applied Mathematics during 1914-1917. From 1917-1923, he worked as Professor at Benaras Hindu University. He gave new dynamics to research and founded the Benaras Mathematical Society, which later changed its name to Bharat Ganit Parishad. This Society played an important role in the development of Mathematics in North India.

Bombay University was started at the same time as Calcutta and Madras Universities, but it produced its first PhD in Mathematics as late as 1942. The reason is that most of the mathematics students from the western region went to Cambridge and got fascinated by Cambridge Tripos. Some of them like Mahajani[3] and Pavate[3] became senior wranglers, came back and wrote good textbooks. They enjoyed solving difficult problems set in Mathematical Tripos and did not lay emphasis on research. Moreover, Bombay University did not have a mathematics department for a long time and there was no professional society based in Bombay.

In North India also, the excellence of a teacher was measured by his capacity to solve difficult Mathematical Tripos problems selected for British textbooks being used in India. In fact, some early researchers were looked down upon because of their inability to solve those tricky and difficult problems. Today, many researchers cannot solve even easy textbook problems, but they still get respect.

The development of Statistics is associated not with the founding of a professional society, but with the founding of the Indian Statistical Institute in 1931 at Calcutta by Prof. P.C. Mahalanobis[3] and the starting of *Sankhya*, the Indian Journal of Statistics by him in 1933. The dynamic leadership provided by Prof. Mahalanobis led to exponential growth of Mathematical Statistics in India, which ultimately placed India firmly on the world map of Mathematical Statistics.

The Indian Statistical Institute also contributed to the development of Operations Research in India, since it was here that Prof. Mahalanobis applied operations research techniques to national planning at the instance of Pandit Nehru. Two other early centres for the study and research in operations research were started in Defence Science Organisation and Delhi University under the leadership of Profs. D.S. Kothari and R.S. Verma[3]. The joint efforts of all these groups led to the founding of the Operations Research Society of India, which has again contributed to the development of both theory and practice of Operations Research in India.

Applied Mathematics was growing under the leadership of Professors N.R. Sen[3], S.N. Bose[3] and B.B. Sen[3] at Calcutta, under the leadership of Prof. A.C. Banerjee[3] at Allahabad and under the leadership of Prof. B.R. Seth[3] and P.L. Bhatnagar[3] at Delhi. Research in Applied Mathematics received a great boost with the founding of the Indian Society of Theoretical and Applied Mechanics by Prof. B.R. Seth in 1956 at IIT, Kharagpur. Applied Mathematics research also developed greatly due to the starting of the five Indian Institutes of Technology, the strengthening of mathematics departments in regional colleges of engineering and the setting up of the Department of Applied Mathematics in Indian Institute of Science at Bangalore.

3. Role of Research Institutes and Advanced Centres

The most prestigious school of mathematics is at the Tata Institute of Fundamental Research (TIFR), Bombay. During more than four decades of its existence, this school has done excellent work of international standard in many areas of pure mathematics.

During this period, hundreds of very distinguished mathematicians from all over the world have visited the school and given series of lectures there. A large number of their lecture notes have been published. The school recruits bright students and gives them an opportunity to interact with mathematicians of the

school and with visiting mathematicians. As a result, more than a hundred good mathematicians have been produced. Some of them have been invited to give addresses at international congresses of mathematicians. The school also organises occasionally summer schools and gives facilities to research workers to stay for short periods at the school.

The fact that we have a school of mathematics comparable with the best in the world is very satisfying. However, it has to be remembered that the total foreign-mathematician-months spent in all the Indian universities with thousands of teachers and research scholars has been much less, in fact almost negligible, as compared with the foreign-mathematician-months spent at TIFR. The university mathematicians have to work under very difficult conditions. They teach 10-18 hours a week, participate in administrative duties and guide research students, working with meagre library facilities. However, because of the large number of research workers involved, the invigorating atmosphere provided by interaction between teaching and research and a large number of dedicated mathematical scientists in the universities, the universities have done reasonably well and have produced 98 per cent of the research work done in India. One can only imagine what could have been the achievements of our scholars if they were given better library facilities, less teaching loads, sabbatical leave facilities, possibilities of greater interaction with distinguished mathematicians, more facilities for participation in national and international conferences, etc.

Another research institute is the Institute of Mathematics Sciences (Matscience) at Madras started by Prof. Allady Krishnaswamy. It has done good work in Theoretical Physics, Pure Mathematics and Stochastic Processes. It also has a Visiting Professors Programme supported by the Department of Atomic Energy. It has now a very distinguished theoretical physicist Prof. R. Ramachandran as its new Director and it is hoped that it will grow fast.

The third research institute is the Mehta Research Institute at Allahabad started by Mehta Trust, but now mainly funded by the Department of Atomic Energy. After the sudden death of its first director, Prof. P.L. Bhatnagar, it was most unfortunate that the DAE could not find a Director for it for six long years. Even then when it appointed a distinguished mathematician, Prof. Shrikhande, as the Director, no significant developments have taken place, since no decision has been taken on the recommendation of the Director about the location of the institute[4].

The fourth research institute has been started by the distinguished mathematician, Prof. Shri Ram Abhyankar, at Pune. The Bhaskaracharya Prathisthan is however making very slow progress, because Prof. Abhyankar has still to perform his duties as professor at Purdue University.

A private trust has decided to start an Institute of Applied Mathematics at Nadiad and the Himachal Pradesh Government has given recognition to Parmar

Institute of Mathematical Sciences at Shimla. However, these have yet to start functioning[5].

Thus, except for TIFR, and to some extent Matscience, other research institutes are not really functional. The total funds spent on all these institutes are less than the funds spent on any one of more than a hundred research organizations supported by the CSIR, DRDO, ISO, DST, ICMR, etc., all of which contribute significantly directly or indirectly to researches in Physics, Chemistry, Biology, etc.

TIFR also started a programme on Applications of Mathematics at Indian Institute of Science, Bangalore. Here also, a large number of distinguished applied mathematicians were invited to give lectures, but in the absence of a core applied mathematics faculty at the centre, this centre did not develop as expected. In fact, the Indian Institute of Science, Bangalore, has a strong Applied Mathematics Department, but there has not been much interaction between this Department and the TIFR programme on Applications. The active Fluid Dynamics Group at Bangalore University has also not been involved. There was, of course, no involvement of applied mathematicians from the rest of the country. The programme has concentrated on some aspects of applicable mathematics.

On the other hand, the atmospheric sciences programme of IIT, Delhi under the leadership of Prof. M.P. Singh has produced a great impact through the interaction of applied mathematicians of the centre with medical and meteorological scientists in the country.

The University Grants Commission (UGC) also decided to support research in mathematics through the advanced centres set up by it at Panjab University, Chandigarh, Bombay University, Bombay, Ramanujan Institute of Mathematics at Madras and the Department of Applied Mathematics at Calcutta University. The last one was the only centre of applied mathematics, while the other three were mainly on pure mathematics. Later, the UGC decided to withdraw recognition from the Calcutta centre. This was done on the basis of the recommendation of a review committee which did not consist of anyone knowing even the elements of the fields of applied mathematics for which this research centre was recognized. On the basis of PhD theses produced and the papers published in international journals, this centre was doing at least as well as the other centres. Fortunately, the West Bengal Government rose to the occasion and continued to support the centre, so that it continues to do its work and organise annual symposia on Applied Mathematics[6].

The University Grants Commission has also provided special assistance to some departments at Bangalore, Jadavpur, Aligarh and Roorkee Universities.

The National Board for Higher Mathematics intends to set up more advanced centres[7]. It is hoped that these centres will play an important role in the development of mathematical sciences in India.

4. Role of the Department of Atomic Energy

More than 25 years ago, the Government of India decided to give the responsibility for the development of mathematics in India to the Department of Atomic Energy. One reason for this was the great interest which late Prof. H.J. Bhabha had in the development of mathematics, and since he was the Secretary of the Department of Atomic Energy, Pandit Nehru assigned Mathematics to DAE. The major argument given however was that since DAE was already looking after the School of Mathematics of TIFR, it would better serve the interest of mathematics if the same agency looked after the interests of mathematics in the rest of the country also. The history of the past 25 years has belied this expectation.

DAE and the Atomic Energy Commission did not have any mathematician with them. The only advice they could get was from those at TIFR, who unfortunately did not have much contact with students and teachers of Indian universities. Prof. Bhabha in his first policy statement emphasized that the main effort of DAE will be on the nurturing and development of mathematical talent in Indian universities. However, after his death, precious little has been done in this direction during the last 25 years. It is true that a few summer institutes have been organised and a few lakhs of rupees have been distributed as research grants in 25 years. However, DAE did not take any steps to consult university professors in general to assess the needs of Indian mathematics. The only conferences (and these were for South Asian countries) were held in the first years and this was when Prof. Bhabha was alive. The main function of DAE continued to be to support TIFR. Most of the members of the mathematical community were not even aware of special responsibilities of DAE.

When CSIR and the Ministry of Education were interested in helping in the development of mathematics, these agencies were told politely that it was the responsibilty of DAE. Scientists in other disciplines can approach many agencies for help, but mathematicians can approach only one agency. This has also resulted in the complete isolation of mathematics from the mainstream of science and technology. On the other hand, one might have expected that mathematics being a responsibility of DAE would have led to greater interaction between mathematics and other sciences.

When the prestigious Indo-American Conference on Mathematics Education and Research held at Banglore in 1973 unanimously recommended the formation of an Indian Council of Mathematical Sciences, DAE did not take any notice of it. In fact, it appears that DAE did not take any notice of any recommendation of this conference attended by 15 American, 3 British and about 45 leading Indian mathematical scientists. At least no visible action was taken.

It was only seven or eight years later, when at the highest level, DAE was urged to do something substantial for the development of mathematics in India, that it appointed a committee to submit a report within three months. The committee

took more than two years and recommended the formation of a National Board for Higher Mathematics (NBHM). The NBHM has been formed, but care has been taken to see that both the Chairman and the Secretarty belong to an institute wholly funded by DAE.

5. Quality of Research

It is not easy to assess the quality of mathematical sciences research in India. However, it is true that in the explosion of the number of PhD theses and research papers, a large number of PhD theses and research papers of poor quality have also been written. At the same time, many excellent theses and many excellent research papers are also being written. It is, however, unfortunate that because of pressures of promotion, sufficient care is not always taken about maintaining standards.

Most universities do not require course-work for PhD degree and the knowledge of a PhD in mathematics may not be more than that of an MSc, except in the narrow area of his specialization. Even here, he may have read only a few papers, modified their results slightly and may have got a degree. Since the supervisors get great credit for producing PhD's, a vested interest has been created. The supervisors take pains to find 'convenient' examiners. Sometimes the over-zealous vice-chancellors make matters worse by appointing only 'distinguished' mathematicians as examiners, without caring to see whether these mathematicians are currently working in the fields concerned or not. The benefit of the ignorance of the examiner goes to the candidate, who gets the degree.

Similarly, a large number of journals[9] are available in India and in some European and Asian countries which do not have a proper refereeing system, which even make money by charging large amounts as 'page charges' and which do not have much circulation. Many Indian authors 'publish' or rather 'dump' their papers in these journals and as such their work is not noticed.

In the prestigious British, American, German and French journals, there is a great competition and there is sometimes even an in-built bias against papers from developing countries. There are some good Indian journals, but unfortunately not all of them are regular. Some of them have even succumbed to the temptation to publish mainly papers of those who can pay reprint charges in dollars.

Since most universities do not have post-MSc level training programmes, research scholars do not receive training in depth. Many areas which require two to three years of hard study before research can be started are not taken up in the universities, while those areas in which research work can be started after six months of study are relatively more popular. This is strenghened by the climate in which degrees are preferred to scholarship.

Many of our young scholars do brilliant research, but this is not on the frontiers. It is not in fashionable areas and as such though it is published, it goes unnoticed.

The Department of Science and Technology organised a number of workshops and conferences to identify 'thrust' areas in physical, chemical, biological and earth sciences, but no similar workshops were organized in mathematical sciences by the Department of Atomic Energy.

A preliminary investigation[10] by the present author has confirmed that there are many fields in mathematics, and these include some very important areas, specially in pure mathematics, in which little research is being done in India and there are some relatively classical fields in which we are doing quite well.

6. Development of Mathematics Education in India during the Twentieth Century

In the first four decades of this century, most of the mathematics education in India followed the British pattern. Even most of the textbooks used here were published in London, Oxford and Cambridge. At schools, we had our own books, but these were mere copies of the corresponding British school textbooks. In fact, in many cases, the books used were those used in England 30 or 40 years earlier and in some cases some books no longer being used in England were being reprinted only for the Indian market.

In the forties and the fifties, winds of change were noticeable. In some universities, courses in modern algebra, linear algebra, general topology, viscous flow theory, magnetohydrodynamics, statistics, ballistics, operations research, etc. were introduced. In some universities, persons trained abroad introduced these courses, but in many others, teacher learnt these subjects through self-study and cooperative study-groups and then taught these courses.

An important step was the organisation of six all-India summer schools at Delhi University by a group of Delhi University teachers. These were organised before summer schools movement started in USA. Highly motivated teachers attended these schools at their own expense and spread the message of scholarship and dedication all over the country.

Later, the National Science Foundation of USA and the British Council provided support to the University Grants Commission and the National Council of Educational Research and Training to organise generously-financed summer schools. The period also saw the birth of the New Mathematics Movement in schools and a trend towards abstract mathematics in universities and colleges. However, by the end of sixties, the new mathematics wave had spent its force and there were second thoughts on too much abstraction and axiomitisation in university mathematics at the cost of applications of mathematics.

There was also a freeze in foreign assistance and the Indian agencies supporting summer schools showed marked lack of enthusiasm for summer schools which had no doubt deteriorated in quality due again to too rapid an increase in numbers.

However, this also meant that most university teachers (though fortunately not all) who had come out to give time to mathematics education went back to their research shells and mathematics education began to suffer in dynamism. The great boom in the prestige for mathematics education activities proved to be short-lived.

However, in this period, about half a dozen organisations of school teachers were formed. They started journals in mathematics education and conducted mathematical olympiads, but due to the slump in the tide, the standards also suffered.

In 1973, we had the Binational Conference on Mathematics Education which produced the valuable document "Mathematics in India: Meeting the Challenge". This conference also marked the end of foreign collaboration in the field of mathematics education.

During the last ten years, NCERT has been mainly engaged in writing of textbooks for schools and UGC has concentrated on College Science Improvement Programme and University Leadership Projects.

The eighties have seen a renewal of mathematics education activities, as is evidenced by the following facts:

(i) The formation of National Board for Higher Mathematics which has already taken many steps to improve the quality of mathematics education and research[8].

(ii) The starting of a journal on Mathematics Education sponsored by the UGC[12].

(iii) The starting of an International Centre for Science and Technology Education sponsored by UGC and the Planning Commission[13].

(iv) The concern which has been expressed by the Indian National Science Academy and the Cabinet Scientific Advisory Committee about the state of mathematics education[14].

7. Role of Mathematical Sciences in National Life

Out of all mathematical sciences, Statistics, Operations Research, Numerical Analysis and Computer Mathematics are already playing important roles in national life. Theoretical Mechanics has had its impact indirectly through its role in aeronautical, civil, mechanical and metallurgical engineering.

However, there are new applications of mathematics in physical, biological, social and management sciences which have not received as much attention in India as they should do..Gauge Theories have produced a good impact on Theoretical

Physics, but these are being studied neither by mathematicians nor by theoretical physicists. There are serious groups on biomedical and ecological problems at Delhi, Jadavpur and Kanpur, but there is a huge scope for work in these areas.

Mathematical Modelling is needed in almost all areas of science and technology, whether it is water resources or oil exploration or economic planning or transportation systems or urban and regional planning or marketing or energy development. CSIR is already planning a conferencee to discuss the problems needing mathematical modelling in all its laboratories[15]. It is hoped that DRDO and Indian Space Organisation will also plan similar conferences to explore the full power of mathematical modelling.

There is already a proposal to form an Indian Society of Mathematical Modelling and Its Applications[16]. There is little doubt that the formation of this society will help in providing a common platform to all users of mathematical modelling.

There is a proposal to start courses in Industrial Mathematics. A symposium on Mathematics in Industry[17], on the lines of similar symposia in UK, USA and Australia, is also proposed to be held.

8. Some Recommendations

(a) There is a great need for research in the history of development of mathematical sciences in India. This should be taken up immediately before the main actors in the development of mathematics disappear from the scene. The statements made in the paper have all to be quantified. The *Mathematical Reviews* and similar other journals have to be scrutinised to arrive at an objective picture and to find the gaps. It is hoped that INSA and the NCHSI will soon undertake this work and give it the priority it deserves[18].

(b) Thrust areas should be identified immediately and active steps should be taken to encourage research in those areas where gaps are identified or which are found to be necessary in national interest[19].

(c) Centres of Research have to be established in different disciplines immediately. Instead of having centres for the whole of mathematics, we should have centres for specified disciplines. The NBHM has to give a high priority to this problem[19].

(d) Mathematics Education Centres have to be established to develop curricula and curricular materials scientifically, to evaluate them, to train teachers, so that we get best results from our limited resources[18].

(e) A National Commission on Needed Support for Mathematical Sciences should be set up immediately on the same lines as a similar commission set up in the USA three years ago, which has produced a valuable document 'Renewing US Mathematics'. We need a similar document on "Renewing Indian Mathematics"[20].

(f) Work done at various institutes of research, advanced centres, IIT's, etc. should be evaluated objectively with the objective of strengthening these centres[19].

(g) The present structure of providing financial support to mathematics has to be examined and a structure which will enable the mathematical scientists to play their full role has to be evolved[21].

9. Bibliographical Notes

(a) Detailed Surveys of Progress in Mathematical Sciences are given in the following reports:

1. B.R. Seth (1963), *Fifty Years of Science in India: Progress of Mathematics*, pp. 44, Indian Sci. Cong. Ass.

2. P.K. Bose (1963), *Fifty Years of Sciences in India – Progress of Statistics*, pp. 50, Indian Sci. Cong. Ass.

3. R.S. Mishra (1972), *A Decade (1963-72) of Science in India: Progress of Mathematics*, pp. 70, Indian Sci. Cong. Ass.

4. P.K. Bose (1972), *A Decade (1963-72) of Science in India – Progress of Statistics*, pp. 26. Indian Sci. Cong. Ass.

5. S.K. Mukerji and B.V. Subbarayappa (eds.) (1984), *Science in India: A changing profile*, pp. 80-88, Indian National Science Academy, New Delhi.

(b) Lists of PhD theses in Mathematics and Statistics are available in[22]

1. A.I.U.: *PhD Theses in Indian Universities*, Association of Indian Universities.

2. M.K. Singal (1977), Doctoral Research in India: *Bull. Math. Ass. Ind.*, 3 (1-4) pp. 4-69.

(c) Life-histories of eighteen of the eminent Indian mathematicians and statisticians of the twentieth century are given in [23]

1. J.N. Kapur (editor), *Eminent Indian Mathematicians of the Twentieth Century*, In 2 Vols., Mathematical Sciences Trust Society, 609, IIT Kanpur.

2. J.N. Kapur (editor), Eminent Indian Mathematicians of the Twentieth Century, *Bull. Math. Sciences India*, Vol. 6 (1974), Vol. 12 (1981) and Vol. 16 (1984).

(d) The proposal for an Indian Council of Mathematical Sciences was spelt out in

1. UGC – *Mathematics in India: Meeting the Challenge*, 1974.

2. The powers and functions of the National Board of Higher Education are given in an article on the subject in *Mathematical Education*, Vol. 1, No. 1, pp. 33-35. This is a quarterly journal sponsored by UGC.

(e) History of Mathematics Education, specially at the school level is given in

1. J.N. Kapur (1978), Changes in Mathematics Education since the late 1950's. Ideas and Realisations – India, *Studies in Mathematics, Netherlands*, **12**, 57-69.

10. Developments during the Last Decade

The previous eight sections gave the text of the invited address given by the author at the Indian National Science Academy Seminar on "SCIENCE, TECHNOLOGY AND SOCIAL CHANGE" 1900 to 1980 on 22 February 1985 at Calcutta. The present section highlights significant developments of the last decade in the form of Notes on the earlier account.

1. The number of PhD theses in mathematics produced after 1980 has been as follows:

81-82	83-84	85-86
469	295	503

Figures for the years 1987-92 are being collected under a project of the Indian National Commission for History of Science. It appears that the exponential growth in the number of PhD theses has stopped and the number of PhD theses may now stabilize at about 2000 per year. The prediction of 3500 theses in the decade 1981-1990 has not been realized. Some possible reasons for this are:

- decreased emphasis on PhD degree in recruitment of lecturers
- brain-drain from mathematics to computer science
- greater perceived attractiveness of administrative services over research
- stabilization in the number of jobs available for mathematics PhD's.

Detailed investigations are being carried out to find how far these hypotheses are true. Trends in the numbers of PhD's produced in other science subjects in the decade 1980-1990 are also examined from this point of view.

A deeper analysis of PhD theses in mathematics has been given in

- J.N. Kapur (1990), "Mathematics PhD theses from Indian Universities", in *Fascinating World of Mathematical Sciences (FWMS)*, Vol. VII. 129-141, Mathematical Sciences Trust Society (MSTS), New Delhi.

2. Further surveys of research in the twentieth century have been given in

   - J.N. Kapur and S.M. Hegde (1989), *"Development of Mathematical Sciences in the Twentieth Century"*, Report of a project sponsored by INCHS. This report is now being updated.

   - D.K. Sinha (1991), In *Report of National Committee on Mathematics Education and Research* (NCMER).

   - UGC Mathematics Panel. Its status report on Mathematics is now being finalised.

3. The biographies of all these mathematicians and the conditions under which they established schools of research are given in

   - J.N. Kapur (1990, 1991), *'Eminent Indian Mathematicians of the Twentieth Century'*, 4 Volumes, MSTS, New Delhi.

4. About two years ago, it was finally decided that the institute would be located at Allahabad itself. The UP Government has allocated a large piece of land for it. Also, Dr H.S. Mani, a theoretical physicist, has joined as the new Director. Its library has also been well equipped with old volumes of mathematics journals. It is hoped that MRI will now make a rapid progress.

5. Despite good intentions, these institutions have not developed as expected. However, the Centre of Mathematical Science in Trivandrum has done good work.

6. A few years ago, UGC re-recognised it as a UGC Advanced Centre for Applied Mathematics.

7. It is expected that NBHM will start its first autonomous centre at Indore.

8. A more detailed account of the role of DAE on the development of mathematical sciences and the support now needed by mathematical sciences is given in

   - J.N. Kapur (1990), "Twenty-five years of mathematics under DAE" In *FWMS*, Vol. VII, pp. 142-146, MSTS, New Delhi.

- J.N. Kapur (1991), "Needed Support for Mathematical Sciences in India", In *FWMS*, Vol. X, pp. 105-125, MSTS, New Delhi.

- J.N. Kapur (1991), "Support needed for Mathematics Education and Research", In *FWMS*, Vol. X, pp. 124-148, MSTS, New Delhi.

NBHM has now been working for seven or eight years. It has given scholarships to MSc students and fellowships for pursuing PhD and post-PhD programmes in mathematics. It has given grants to mathematicians for attending foreign conferences and to mathematicians abroad for visiting India. It organised an international symposium on Ramanujan in 1987 and a conference on Development of Mathematics in India. It has also sponsored a Newsletter. One major function it has performed is to organise Indian Olympiads (INMO's) and to send Indian teams to participate in international mathematical olympiads. It has also organised some summer schools.

9. A list of Indian journals is given in

   - J.N. Kapur (1991), "Indian Journals on Mathematics Education and Research", *Mathematics Newsletter*, Vol. 1, No. 4, pp. 7-8.

10. More details are given in 2 (a).

11. A more detailed history of mathematics education in India from the Vedic times is given in

    - J.N. Kapur (1991), "A brief history of mathematics education in India", in *FWMS*, Vol. VII, pp. 109-116, MSTS, New Delhi.

    A more comprehensive history of mathematics, science and technology education is given in

    - S.N. Sen (1991), "*Scientific and Technological Education in India 1781-1990*, Indian National Science Academy.

12. Its seven volumes have been published and its eighth volume is in press. It is being funded by UGC, edited by an editorial board headed by the present author and is being published by Wiley Eastern, New Delhi.

13. Unfortunately, the centre did not go beyond the planning stage.

14. A still stronger support was given at the platinum jubilee session of the Indian Science Congress held in January 1988 at Poona, by the then Prime Minister of India, late Shri Rajiv Gandhi, who in his inaugural address strongly urged that mathematics education and research, so long neglected, should receive prior attention and adequate support.

The Mathematics Section of the Indian Science Congress also urged that an Indian Council of Mathematical Sciences should be formed and that the Department of Science and Technology should support mathematical sciences through a mathematical sciences committee in the same way it is supporting other sciences.

The Indian Mathematical Society held a National Conference on Support Needed for Mathematical Sciences and strongly supported these recommendations. These recommendations were forwarded by the P.M.'s Office to the Cabinet Advisory Committee on Science which held a one-day meeting to specifically discuss these recommendations. It recommended multiple funding for support to mathematical sciences.

The Task Force of DST considered these recommendations and appointed the National Committee in Mathematics Education and Research (NCMER) with Prof. P.K. Bose as chairman to prepare

(i) a status report on mathematics education and research keeping in mind the need for strengthening those areas needed for developing science and technology in the country,

(ii) to make a study of pattern of funding mathematical research *vis-à-vis* the role of DAE in this regard,

(iii) to explore the possibility of financial support in respect of mathemattical sciences from DST and similar funding institutions, and

(iv) to study in depth the proposal for setting up an autonomous Indian Council of Mathematical Sciences by the Government of India so as to coordinate and accelerate programmes and activities in mathematical research.

NCMER worked for three years and produced a report entitled "Mathematical Education in India: Reality, Perspectives and Strategies'. The report included a set of valuable recommendations. Some comments on these are given in

- J.N. Kapur (1992), "Some Comments on recommendations of NCMER", *Math. Education*, Vol. 8, No. 1.

NBHM held a national conference on the Development of Mathematics in June 1990. Its recommendations and comments on these recommendations are given in

- J.N. Kapur (1990), "Some comments on the recommendations of NBHM Conference on Development of Mathematics", *Math. Education*, Vol. 1.

Implementation of recommendations of both these conferences will go a long way in renewing Indian mathematics.

15. This conference was held at NGRI, Hyderabad and as a consequence of its recommendations, CSIR has set up a National Mathematical Modelling Centre at NAL, Bangalore as a national facility for all CSIR laboratories. Mathematical Modelling has also been recognized as a thrust area for the development of science and technology in India.

16. Instead of this society, another society, 'Indian Society for Industrial and Applied Mathematics', has been formed, and a large number of mathematicians, scientists and engineers have already joined it as founder members.

17. Two symposia in Industrial Mathematics have been organised under the auspices of the Indian Mathematical Society and some universities have already started courses in Industrial Mathematics.

18. Since then the National Commission on History of Science in India has been renamed as the Indian National Commission for History of Science. It also sanctioned a project on Development of Mathematical Sciences in India in the twentieth century.

19. No steps have so far been taken to implement these recommendations. However, all these are included in the recommendations of NCMER and NBHM.

20. NCMER and NBHM have produced valuable documents, which may be called 'Renewing Indian Mathematics'. What is needed now is their implementation.

21. NCMER has already recommended that mathematics should be multiply funded and special funds should be provided by DST.

22. A more comprehensive list of PhD theses is given in 2(a). This list is being updated till 1990.

23. Two more volumes of this series have been published and the fifth one is under publication.

11. Challenges of History of Mathematical Sciences of the Modern Period

Though a significant amount of research has been done on ancient mathematics, relatively very little work has been done about the development of mathematical sciences in the twentieth century. However, the study of the modern period is even more urgent than that of the ancient period for the following reasons:

(i) All those who created ancient period mathematics have gone and all the manuscripts which have survived are going to be with us in future. On the other hand, those who are creating mathematics in the modern period are gradually passing away and the documents and reminiscences on which the history of the modern period can be based are gradually disappearing. We should use these valuable resources before it is too late.

(ii) If we study trends in growth of mathematical sciences in time, we can always take corrective action before it is too late.

(iii) Students need to be informed about the current and relevant areas of research, because in the absence of this information they may be misled into choosing out-of-date research areas and their talents may be wasted.

It is for this reason that in western countries, regular studies are carried out on a continuing basis about PhD's being produced in different disciplines and the resulting excesses and shortages, about enrolment of students in different courses, about demands from users and industry, about thrust areas in research, etc. These studies are used by the government and the mathematical community to adjust policies, so that education and research in mathematical sciences continuously respond to the needs of the society. In USA, they interviewed about a hundred of their senior mathematicians about their reminiscences and their views.

In India, we do not have any hard data about the rate of fall in enrolments in BSc, MSc and PhD programmes, about those areas of research which are needed by the country but in which little research is going on, about the large number of unqualified tearchers who are teaching mathematics in our schools, about the number of teachers who need retraining in mathematics, about the number of users who need advanced courses in mathematics and so on. In the absence of such studies and data, we take some action, but we find that the situation does not change, because the actions are not commensurate with the needs of the situation.

NCMER completed its three years' work, but throughout it felt the lack of scientific studies and data which alone could have made it possible for it to make quantitative assessments and quantitative recommendations on which the government could have acted. Now its recommendations say that some action should be taken, but on what scale it should be taken and how much expenditure it would involve, is anybody's guess.

It may be debated as to which agency should undertake these studies, i.e., whether it should be UGC or NBHM or DST or NCERT or CSIR or INCHS or the professional societies or the mathematicians with support from funding agencies or the Planning Commission. If the Indian Council of Mathematical Sciences is to be formed with a proper secretariat of its own, then this task can very well be assigned to it.

A more or less similar situation holds in the case of other sciences, but there some studies are always made for the sake of modern technology, which requires these sciences immediately. Even there, those aspects of the sciences which are not immediately required are not taken care of.

The Indian National Commission on History of Sciences is already seized of the problem and it is hoped that its committee for the modern period will commission such studies in all sciences in a planned manner.