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Mathematics Education

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INTRODUCTION

The present trend report is based on an analysis of 29 Ph.D. theses, 9 M.Phil dissertations, 5 research reports and 4 research articles which appeared in this period. There is some improvement in the number of Ph.D. theses now as compared to what it was during the first 25 years after Independence when there were only 10 Ph.D. theses. However, the trend report for the Fourth Survey of Research in Education was based on 70 studies, which included studies conducted in earlier periods, also; this shows that the output is still very small when we consider the large number of research problems requiring immediate attention, the diversity of conditions in the country and the fact that the USA alone produces about three to four hundred theses per year. We do not yet have independent departments of mathematics education, nor do we have many professors of mathematical education in India though we have some professors of education who take interest in mathematics education and some professors of mathematics who are interested in research in mathematics education.

Only 23 departments of education out of more than one hundred such departments have produced any theses on mathematics education in this period, in spite of the fact that mathematics education is probably the most important area concerned with school education and its importance is vital for the development of science and technology in India. We spend hundreds of crores of rupees on teaching mathematics in India, yet we spend very little on research on mathematics education which would enable us to give better quality education to our students.

REVIEW OF REASEARCHES IN MATHEMATICS EDUCATION (1988-92)

In the next four sections, we shall describe the research done during this 5-year period and summarise the main findings of this research. In the subsequent sections, we shall analyse the strengths and weaknesses of this research, the trends that this research indicates, the research that is needed and the steps to be taken to accelerate the pace of research in mathematics education.

Research in high failure rates in mathematics

This is certainly a matter of great concern to all the parents, all members of the public and all educators and as such some researchers have sought to analyse the causes of the high failure rate in mathematics and to suggest steps for reducing the same.

Jain, S.L. and Burad, G.L. (1988) have found the following **causes as responsible for low results in secondary mathematics in Rajasthan**: non-availability of mathematics teachers due to late appointments and frequent teacher transfers; lack of appropriate classrooms, blackboards and other physical

facilities; irregular attendance of students; low standard in the lower classes; non-availability of textbooks; lack of timely correction of homework; overburdened and uninteresting curriculum; lack of child-centered teaching; insufficient periods for teaching mathematics; and lack of suitable teaching aids. They have, however, not analysed why these causes affect mathematics more than other subjects.

Kasat, B.S. (1991) has made an in-depth study of the **causes of failures in the S.S.C. examination of Marathi-medium high school students in Palghat Tehsil**. He examined two hundred boys and girls who had failed and found that most of them had poor intelligence, poor numerical ability, poor comprehension and recall ability, no interest in mathematics, poor study habits, lack of help from parents and teachers, and difficulties in certain topics in the course. They have not suggested steps to enable such students to do better in the examinations.

Chel, M.M. (1990) has examined the problem of **underachievement in compulsory mathematics in the Madhyamic examination** of West Bengal. He found the following causes responsible for underachievement: gaps in knowledge of concepts, difficulties in under standing of mathematical language, lack of openness and flexibility in teaching, difficulty in mathematisation of verbal problems and interpretation of mathematical results, the abstract nature of mathematics, fear and anxiety on the part of the students. They suggest greater motivation of the students for learning mathematics, removal of fear of mathematics, and clearer presentation of the subject based on the needs of the children.

Research for Improvement of Learning and Teaching of Mathematics

The main object of mathematics education research is to be of help in improvement of classroom learning and teaching. It is, therefore, natural that a large number of research studies should be concerned with different aspects of this problem. This improvement can be brought about through studying the characteristics of effective teachers of mathematics; through the use of computers, computer assisted instruction and programmed learning; through analysis of errors committed by students and development of efficient remedial packages to reduce the same; through improving the attitudes of students towards mathematics; through developing a more positive attitude towards homework in mathematics of both students and teachers; through understanding the styles of learning of high achievers, average achievers, and low achievers; through study of cognitive factors underlying the learning of mathematics; through the study of dependence of learning of mathematics on the personality and tempera mental characteristics of the students; through the use of audio-visual aids, enrichment materials and number games; through the study of SES and environmental factors like father's and mother's education and profession, types of school, etc., on learning of mathematics; through development of special teaching materials for mathematics for special groups; through development of packages of divergent-type problems and skills in problem-solving; and through comparison of different social and psychological factors on the learning of mathematics.

Given below is a brief summary of the research contributions on each of these aspects made in the period under review. Dandapani, C. (1992) has developed a discriminant function depending linearly on eleven variables representing problem-solving, skill, review, reinforcement, assignment, organisation of subject-matter, warmth of the teacher, planning, preparation, concept teaching and the valuation, to distinguish between effective and non-effective mathematics teachers. Effective teachers and non-effective teachers differ in all the eleven aspects. The teachers' perception of mathematics is found to vary significantly with their years of experience but does not vary with their qualifications, the types of school or the place of work or teaching load. Female teachers are found to have significantly higher perceptions

than male teachers. Two major dimensions are identified as problem-solving and reinforcement.

Nagar, N. (1988) has examined the usefulness of computers in teaching mathematics, areas in mathematics which can be taught more effectively through computers and the status of computer-aided teaching of mathematics. This is a survey report of three projects and ten research studies carried out in other countries. It will be useful if our research workers carry out similar research studies under Indian conditions.

Singh, R.D. (1992) has discussed the relative merits of teaching mathematics through computer-assisted-instruction and conventional methods of teaching. Computer-assisted-instruction was always found superior, but the gains were more in the case of good students and there was a definite positive change of attitude towards learning mathematics on the part of both boys and girls due to the use of computers .

Prabha, R. (1992) has found that programmed learning of mathematics is superior to conventional learning of mathematics and that mother's and father's education as well as mother's profession significantly affect programmed learning. Even parent's income and caste affect significantly the learning of mathematics.

Raman, J. (1989) has identified the errors committed by students in calculus under four categories, viz., entry behaviour, perceptual, conceptual and computational, and found that the errors most students committed were conceptual errors followed by computational errors, entry-behaviour errors and perceptual errors. Raman, J. (1989) has developed a remedial package which reduces all types of errors significantly.

Sarala, S. (1990) has analysed the conceptual errors of secondary schools students in learning selected areas in modern mathematics and has found that the number of errors are quite large, and these errors are influenced by sex, locality of the school, management of the school, intelligence, study habits and socio-economic status. The errors decrease with intelligence.

Doshi, P.C. (1989) has studied the possible relationship between achievements in mathematics and cognitive preference styles. For all students the questioning style is the last, while for the majority of arts and commerce students, the recall style is the first. No significant relationship is found between cognitive preference styles and mathematics. It is an open question worth investigation whether by changing teaching strategies we can change the cognitive preference style, and whether this can lead to significantly improved learning of mathematics.

Lalitha Bai, T.K. (1992) had identified the cognitive factor structures of High Achievers (HA), Average Achievers (AA), Low Achievers (LA). For the total sample the 31 cognitive variables reduce to a single factor, viz., numerical ability; for the HA group, these reduce the three cognitive factors, viz., abstract reasoning, numerical spatial facility and non-language reasoning; for the AA group there is a single factor, viz., mental ability; and for the LA group, two factors are identified, viz., numerical-perceptual ability and numerical facility. It will be interesting to see how this research result can be used in actual classroom teaching.

Khatoon, F. (1988) has studied the relationship of mathematical aptitude among boys and girls with interest and vocational preferences. Though Khatoon, F. (1988) finds no significant difference in the aptitude for mathematics among boys and girls, Khatoon, F. (1988) found a significant difference in the achievements. Vocational preferences are influenced by environment factors like the occupation of the father; in general, boys prefer vocations related to mathematics.

Rosaly, A. (1992) has found that the attitude of high school students towards the learning of mathematics and their achievements in mathematics are highly correlated and that urban boys and girls have a more positive attitude towards mathematics than rural boys and girls.

Hariharan, D. (1992) has developed measures to measure the attitude of high school students towards homework in mathematics, and to measure their academic achievement in mathematics, and tried to find out the relationship between these measures, if any. The researcher finds that girls, urban students and private school students have a more positive attitude towards homework in mathematics than others and that students with this positive attitude towards homework have better academic achievements in mathematics. Hariharan, D. (1992) advocates that every mathematics teacher should assign such homework in mathematics as can develop a positive attitude towards it.

Deshmukh, V. (1988) has studied the correlation of mathematics learning and certain personality variables of the students. Deshmukh, V. (1988) finds small but positive and highly significant correlation between mathematics learning and responsible and ascendant temperaments. Deshmukh, V. (1988) also finds low but negative and highly significant correlation between mathematics learning and three temperamental dimensions, viz., sociable, accepting and impulsive. IQ and reasoning are found significantly related to dimensions, ascendant, responsible, critical, and plentiful. The temperamental profiles of high, average and low achievers are found to differ significantly from each other. These are also found to be correlated with the socio-economic-status of individual students. Deshmukh, V. (1988) does not, of course, go into the reasons why students with certain temperamental characteristics should do well in mathematics.

Pal, A. (1989) has considered the dependence of achievement in mathematics on four variables of the affective dimension, viz., self-concept, anxiety, attitude and academic motivation. He formulates 56 hypotheses relating to these variables and classification of students into urban, semi-urban and rural students and male and female students. Pal, A. (1989) finds the regression equation to predict the performance in mathematics as a linear combination of the four affective variables.

Pandhari, A.S. (1988) has studied the effect of language, memory and process on student's learning of mathematics. Pandhari, A.S. (1988) finds that all these influence learning but the type of the student's institution does not affect this learning.

Nalayini, S. (1991) has examined the effectiveness of using number games to teach arithmetic. In eight of the comparisons made, five have shown significant improvement due to supplementary use of number games. Such a study should be conducted particularly for children from backward classes, first-generation learners and others who otherwise show lack of interest in mathematics. It will be worthwhile to find out whether number games can lead to increase in interest in mathematics.

Wagh, S.K. (1991), has developed a multi-media instructional system for remedial purposes for fractional numbers and has expectedly found that this package leads to better understanding than the conventional remedial methods.

Setia, S. (1992), has found that the rapid, average and slow learners differ significantly in their intellectual and socio-economic status levels and that the intelligence, SES, personality and adjustment of rapid, average and slow learners cluster together with achievement in modern mathematics. It will be useful to carry on a companion study of actual correlation of achievements of students in mathematics with intelligence, socio-economic status and personality.

Thind, S.K. (1990) has found, rather unexpectedly, that socio-personal factors such as education of father and occupation of father or mother have no significant effect on the problem-solving ability in mathematics of school-children. However, the education of the mother was found to have a significant effect on the problem-solving ability of the children of Classes VII and IX.

Mishra, R. (1991) has shown that with appropriate teaching strategies even arithmetically disabled children can learn addition and subtraction. However, such

improved techniques have to be developed by painstaking research.

Bhagwat, S.A. (1992) has prepared a package of divergent production type problems in mathematics and has found that the use of this package significantly helps in the development of divergent thinking abilities in both boys and girls. This appears to be a useful effort for development of creativity among school-children.

Krishnan, N.J. (1990) has found that there is no significant relationship between Identification of Problem Solving Strategies (IPSS) and either Applications of Problem Solving Strategies (APSS) or Achievement of Problem Solving in Mathematics (APSM), though the last two are significantly correlated. The essential problem in school mathematics is how to teach problem-solving strategies to students so that they may become efficient problem-solvers.

Biswal, J. (1988) has studied creativity in mathematics as a function of study habits (SHM) and pupils' perception of teachers' impression about their performance in mathematics (PPTIM). It was found that pupils' creativity in mathematics is a linear function of each of the variables SHM and PPTIM. The product correlation in both cases is positive.

Shankara Narayanan, B.L. (1990) has found that guided discovery learning is always better than learning under reception conditions. However, the students of high intelligence perform better and the students with anxiety perform worse under both systems. The first-order interaction between the method of instruction and level of intelligence is found to be significant, but the corresponding interaction between the method of instruction and anxiety is not found to be significant.

Vasanthi, R. (1991) has investigated the relationship of certain psychological, social and educational factors with mathematical learning disabilities. The disabilities considered are: Agrosia, Mixed, Laterality, Up and Down confusion, Asyanbolia, Starephosyanbilia, Reversal of Numbers, Front-Back confusion, Time and Distance confusion, Acalculia and Perceptual problems. These have negative relationship with behaviour problems. Mathematical Learning Ability is greater among monolinguals than in bilingual students. MLA also depends on type of schools.

Yadav, C.P. (1988) has found that there was no difference in the attitude towards modern mathematics of male and female teachers, more experienced and less experienced teachers and postgraduate and undergraduate teachers.

Samuel, F. (1989) has found that Piaget's main theses that the conceptual process follows stages of development and there are stages of development from perceptual reasoning to concrete-logical reasoning, are confirmed under Indian conditions. Samuel, F. (1989) has also found that there is a relationship between the mental ability of children and their ability to understand the concepts of conservation of area, mass and volume.

Special Problems of Learning and Teaching of Geometry

Out of all the topics in the school mathematics curriculum, geometry has attracted the greatest attention of research workers though students find even greater difficulty in following algebra than they find in geometry. Also there has been little research in problems of learning and teaching of calculus, probability, statistics, coordinate geometry, trigonometry, numerical methods, vectors, matrices, etc., all of which are in the school syllabus, some of them even at the secondary level. One reason for this may be that education department researchers may not feel very comfortable with some of these areas. This shows the need for mathematics department educators to take the initiative in research in problems of learning and teaching in these areas.

Given below is a summary of the research work done in the area of geometry during the last five years.

Dutta, A. (1990) has discussed diagnosis and prevention of learning disabilities in the

reasoning powers of the students in geometry. Dutta, A. (1990) finds that the disabilities are there because the teaching of geometry is geared to the needs of the most able students; there are no experiments to strengthen the teaching of geometry; and the relation of geometry and physical space is not explored. Dutta, A. (1990) finds that the use of audio-visual materials leads to greater interest, clearer understanding and longer retention of geometrical concepts. The teaching of geometry has been a subject of debate and Dutta, A. (1990) has made some contribution to it. More research is needed here.

Gurusamy, S. (1990) has attempted to diagnose the errors committed by students of Class IX in solving problems in geometry, and has developed a remedial package. It is claimed that the remedial package leads to considerable reduction in errors in geometry by the students.

Kaul, P. (1992) has found a close relationship between the maturation of the concept of space, mental imagery and the polygon among the middle and secondary schools of Delhi.

Obad, M.M.A. (1989) has examined the relationship of maturity of the space concept and mental imagery with the concept of the polygon (triangle and quadrilateral) but Obad, M.M.A. (1989) has conducted the study with Classes V and VIII of schools in Aden and Obad, M.M.A. (1989) finds the same close relationship as found by Kaul, P. (1992).

Rawool, S. (1988) has found that in geometry, students fail at 'understanding' and 'applications' levels. They use assumptions not covered by the axioms and their explanations are not based on assumptions made.

Sen Gupta, D. (1989) has found that the understanding of axioms in geometry as self-evident truths occurs in the course of growth between the ages of 5 and 7 and the order in which children understand axioms is different from the order in which the axioms are given, though different children understand different axioms at different ages.

Yadav, R.S. (1990) has investigated the relationship of school environment and socio-economic status with the formation of geometrical concepts. Yadav, R.S. (1990) found that all the three factors, viz., age (A), socio-economic status (SES), and school environment (SE) have significant effects on concept formation in geometry. At the primary stage, A is most important, SES comes next, and SE is the least important. At the middle school level, SE is the most important, SES comes next, and A comes last.

Evaluation of Curricula

Mathematics curricula are made in all the states in India and implemented, but these are seldom evaluated to see whether in practice these serve the objectives that have been laid down for the learning of mathematics. Even if there is some evaluation, it is rarely used for improvement of subsequent curricula. In the period under review, an effort was made to evaluate the mathematics curricula of Orissa and Gujarat (primary level) and of NCERT from the point of view of Piaget's approach. It is necessary that we should have similar evaluations of all the 20-25 mathematics curricula in the country, each of these at primary, junior secondary, secondary and senior secondary levels, at least once every five years, so that we have to have at least 25 research studies in evaluation of curricula every year and we have also to see that these evaluations are used to improve the subsequent curricula. (It is desirable that evaluation is done with respect to criteria for Mathematics Education laid down in the National Educational Policy document and also with respect to the objectives laid down, in the prefaces to the various curricula themselves. Quite often nice objectives are laid down, but they are ignored when framing the curricula or implementing them.)

We give below the summaries of the three evaluations of curricula in this period.

Mohapatra, B.C. (1990) has made a critical appraisal of the secondary school mathematics curriculum of Orissa and found that: (1) the objectives of teaching mathematics are clearly

defined, (2) the mathematics teachers are conservative, (3) the students realise the importance of mathematics, (4) geometry is better discussed than algebra, (5) teachers do not use the discussion method, (6) correct home assignments are not always given, (7) diagrams in textbooks are inadequate and (8) there is a great need for in-service training of teachers.

Sarangapani, P.M. (1990) has analysed the primary schools curriculum from the Piagetian perspective and found an overall mismatch. It appears that the curriculum designers have never taken into account the various stages of the mental development of children. The teaching is too abstract, algorithmic and ambitious and does not recognise alternate strategies. The exercises given to children are mostly drill exercises for computation. There is no scope for freedom to learn or to learn through the play way.

Shah, P.A. (1992), has evaluated the primary school syllabus of Gujarat by carrying out a large sample survey of students' performance and teachers' opinions. The teachers of Classes I and II feel that the syllabus could sustain the interest of the students, but the teachers of Classes III and IV do not agree with this view. Some difficult topics in the syllabus have also been identified. About half the teachers were found to be using appropriate audio-visual teaching aids.

Some Comments on Research Findings

1. Usually research activity in most fields in our country is large in quantity, but is, in general, poor in quality, but in the field of mathematics education, the quality of research is good, but quantity is poor.

2. The NCERT is doing an excellent job of disseminating the results of the research in all fields of education. However, this is not enough if these results have to reach and influence the classrooms. In all the developed countries, the professional associations of educators and teachers perform this role through their conferences and journals. In India, also, these associations should bring the results of research to the notice of the school-teachers in the country, and the NCERT and other funding agencies should support them in this work.

3. Most of the researches are based on individual efforts and there is little evidence of coordination. The individual M.Phil. or Ph.D. scholar and his or her supervisor choose a problem and draw up a suitable plan of action. The investigation is carried out and the student gets his or her degree. There is a very little follow-up of research. We should have more planning of research in mathematics education at the national level and the NCERT and state governments should fund research projects in areas in which research results are urgently needed.

4. In mathematics education, both research and development should go together; and it is time that the utilisation of research should be considered as important as doing research.

5. We have differences on account of sex, religion, caste, educational background of parents, type of institution, socio-economic-status, rural/urban, semi-urban locations, different ways of presenting of a subject, different methods of evaluation, different discipline of mathematics, different levels at which problems arise—and many other types of differences. If we consider all these, we have thousands of problems to investigate and very few researchers to do the investigating.

Some Topics in Mathematics Education in which Research is Needed

1. Teaching of algebra/trigonometry/vectors/calculus/matrices/probability/statistics/numerical methods, etc., in schools.
2. Teaching of applications of school mathematics to school students.
3. Use of mathematics projects for students to encourage creativity in mathematics.
4. Use of mathematics applications projects

to create interest in applications of mathematics.

5. Integration of mathematics and science teaching at all levels.
6. Development of special strategies for teaching first-generation learners, children from backward classes, and physically and mentally handicapped children.
7. Development of special strategies for teaching mathematics to children of tribal and hill areas.
8. Use of calculators to improve the teaching of school-mathematics.
9. Integrating the use of calculators with the rest of school-mathematics.
10. Use of computers for teaching mathematics.
11. Use of the mathematics laboratory for teaching mathematics.
12. Use of history of mathematics for improving teaching of mathematics.
13. Use of audio-video cassettes and films in improving of teaching of mathematics.
14. Curricula for in-service training of teachers.
15. Evaluation of present in-service programmes from the point of view of their effectiveness and adequacy.
16. Alternative methods, including distance education, for training of mathematics teachers.
17. The impact of textbooks on the learning of mathematics.
18. The impact of olympiads on the attitude of students towards mathematics.
19. Integration of teaching of mathematics with the teaching of other school subjects.
20. Role of mathematics clubs and recreational mathematics in the teaching of mathematics.
21. Use of graphic calculators in schools.
22. Teaching problem-solving strategies.
23. Teaching students to pose problems in mathematics.
24. Use of guided-discovery for the freedom-to-learn or the pattern-recognition approach as against the present lecture method of teaching mathematics.
25. Enrichment of school mathematics through problems from industry.
26. Identifying and nurturing talented students.
27. Evaluation of present mathematics textbooks.
28. Evaluation of present mathematics curricula.

It is hoped that the person who prepares the next trend report will be able to report significant progress on some or all of these problems.

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