SUMMARY

A nationwide project on children with mathematical disabilities in 2002 at University of Missouri by David C. Geary can be considered as initiation of a movement with prime focus on mathematical disability and difficulty in school students. Since then researchers and behavioural scientist across the world are trying to decipher plethora of issues involved in the field. Recent articles published in leading Indian newspapers across India are also talking about the poor performance of Indian school students in Mathematics and English. Undeniably, it can be concluded that mathematical disability has created hue and cry among the general population as well as psychologists.

Although initial interest in the study of people with disabilities in mathematics dates back to a century ago, recent efforts seem focussing specifically on mathematical learning disabilities in childhood (Iglesias-Sarmiento & Deano, 2011). This research scenario appears in somewhat contrast with the social interest generated by the issue. The curricular domain of mathematics includes a high percentage of academic failure, and research publications indicate the prevalence of the difficulty somewhere around 4 to 10%. However the percentage of incidence varies country to country. The Programme for International Student Assessment (2006) has revealed that, in the case of Spain, 8.6% of the students did not even reach the minimum level.

The investigators have also paid attention to the cognitive mechanisms underlying the mathematical deficit. Two relatively contrary positions can easily be traced in the current mathematical disabilities literature. The first position has shown that Mathematical Learning Disabilities are the result of specific deficit in numerical representation (Dehaene, 1997; Landerl et al., 2004). The second theoretical perspective, which was at the focus of this study, is based on the relationship between
mathematical ability and diverse basic cognitive processes. From this position, researchers usually have focussed their efforts in understanding the functioning of the underlying cognitive processes and their mediating role in mathematical achievement. On the basis of some indications from the studies of Adams and Hitch (1997), Passolunghi and Siegel (2004), and Swanson et al. (2004) we presumed important role of the different components of working memory and PASS cognitive processes in mathematical learning disabilities.

With all focus and attention set on mathematical disabled children, there exists a category of low mathematical ability students, which is often overlooked. This negligence, on the part of educators as well as researchers, might be due to increased teacher-student ratio, emotional and behavioural issues of these students and a common viewpoint that these students just may not be focussing properly on their performance. However, concern of this study was such students and the underlying role of various cognitive processes in mathematics. From the available literature it has become clear that mental mathematics involves well-learned procedures, problem solving skills, and reliance on short-term and working memory, or other basic cognitive processes. A common view is that normal adults have available a vocabulary of known sums, products, and so on, which are organised in the form of an associative semantic network. However, there is a continuing debate among the authors of the various models as to the nature of cognitive processing that might be involved or how the necessary skills are acquired and applied by young children (e.g., Koesbergen et al., 2011). Despite the debate, most researchers in this area agree that there is a requirement for temporary storage of information during calculation in addition to any other processes that might be involved. Therefore, the individual differences in working-memory capacity may underlie the cognitive deficits in mathematical achievement.
There is some research evidence that mathematical reasoning is facilitated by the individual’s capacity to interrelate spatial images and verbal propositions. Various studies have shown that students with a high ability to solve spatial problems achieve good results in science and mathematics (e.g., Bodner & McMillen, 1986; Diezmann & Watters, 2000; Wai, Lubinski, & Benbow, 2009). The relations between spatial ability and individual characteristics may be reconsidered from Das et al.’s (1994) PASS model. From this theory, spatial ability can be understood in simultaneous and quasi-spatial formats. Thus, tasks associated with spatial ability such as mathematics seem to be easier for students who process information simultaneously rather than sequentially. Likewise, performance in other tasks such as conservation, transitive inference, or class inclusion is higher in children who use simultaneous processing rather than successive processing.

Even outside of the sphere of the PASS theory, some studies (Fuchs et al., 2006; Krajewski & Schneider, 2009; Passolungui et al., 2007) have analyzed the relation between the level of phonological ability and performance in diverse mathematical and arithmetical tasks. The significant relation between simultaneous and successive processing and phonological processes has been confirmed by Joseph et al. (2003). But the results of studies of the relation of phonological processing and mathematical performance are still inconclusive. Although in various studies the importance of phonological processing and specifically of phonological awareness in early arithmetic performance has been pointed out, other investigations (e.g., de Jong & van der Leij, 1999; Passolungui et al., 2007) have found no predictive relations. Hence, more studies with cognitive processes of this kind are required.

Therefore, the proposed investigation focused on the study of mathematical difficulty in children and their underlying cognitive skills. A test based on a theory like the PASS seemed particularly useful, not only for
diagnosis and instruction but also to provide information about the
cognitive strengths and weaknesses of low mathematical ability children,
which are especially relevant to design instructional and specific
intervention programs and because of its reassessment of cognitive
capacities. In view of these indications, the title of the present study was
stated as: ‘Working memory, PASS cognitive processes and achievement
deficits in children with low mathematical ability’.

Objectives
1. To examine the Working Memory Capacity among children with low
and normal mathematical ability.
2. To examine the PASS cognitive processes among children with low and
normal mathematical ability.
3. To examine the Overall Achievement level among children with low
and normal mathematical ability.
4. To study the relationship between Working Memory and Achievement
Deficits in children with low mathematical ability.
5. To study the relationship between PASS processes and Achievement
Deficits in children with low mathematical ability.
6. To examine the joint contribution of Working Memory and PASS
processes in predicting Achievement Deficits in children with low
mathematical ability.
7. To examine the extent to which Working Memory, PASS processes and
Achievement Deficits differentiate between low and normal
mathematical ability groups.

Hypotheses
1. Low mathematical ability children would be lower in Working Memory
Capacity than normal mathematical ability children.
2. Low mathematical ability children would be lower in PASS cognitive
processes than normal mathematical ability children.
3. Low mathematical ability children would have greater degree of Achievement Deficits than normal mathematical ability children.

4. Achievement Deficit of children with low mathematical ability would be negatively related to their Working Memory capacity.

5. Achievement Deficit of children with low mathematical ability would be negatively related to their PASS cognitive processes.

6. Working memory and PASS processes would contribute substantially to the prediction of Achievement Deficits in children with low mathematical ability.

7. Working memory, PASS processes and Achievement profiles are likely to differentiate successfully between low and normal mathematical ability groups.

**Method**

*Participants:*

Initially, eleven high schools drawn from three districts of Haryana were surveyed for the identification of low mathematical ability children. A total of 840 students of 6th and 7th grade were tested on a twenty-item Mathematical Ability Test. The subjects scoring below 25th percentile were diagnosed as low mathematical ability cases (target group) and those who scored above 40th percentile were placed in normal mathematical ability group (comparison group). The inclusion criteria were that children were free from visual or hearing impairment, motor disability, serious brain damage and mental retardation. It was also confirmed that the selected children were not deficient of learning opportunities and their learning disability, if any, was not attributable to their lack of motivation and severe emotional problems. The final sample comprised of 291 children, 143 (96 male & 47 female) in low mathematical ability group and 148 (99 male & 49 female) in normal mathematical ability group. The age of the subjects ranged between 10 to 12 years.
**Measuring Instruments:**

Following measuring instruments were used in data collection.

1. Operation Span Test- The Operation Span task is a subtest of working memory designed by Turner and Engle (1989). In operation span task, subject receives a series of simple arithmetic problems one by one, each followed by a lower case word. The subject reads aloud and solves the problem and then reads the word given after each problem/post-fixed word. At the end of operation-word string, on a signal, subject is to recall the words that followed the operation strings in the correct order. The string size recalled correctly by the subject is the operation span score on at least two of three trials for all set sizes.

2. Reading Span Test- The Reading Span test developed by Daneman and Carpenter (1980), is a measure of working memory. This test presents sentence-word strings of different sizes. The subject reads aloud the sentence and then reads aloud the word in capital letters. At the end subject is to recall the words that followed the sentences the same way. Subject is to remember unrelated words printed at the end of the sentence. The string size recalled correctly is the OS score with a minimum criterion of two perfect recalls of three trials.

3. Counting Span Test- The Counting Span test of working memory was designed by Kurland and Goldberg (1982). The test requires subject to recall the number of stimulus figures presented in different set sizes. The stimulus figures are embedded with figures either same in shape but different in colour or different in shape but same in colour. The task of the subject is to recall the number of stimulus figure presented in sequence. The number of sets correctly recalled is the counting span score.

4. Cognitive Assessment System- It has been developed by Naglieri, Das and Kirby (1997) to evaluate Planning, Attention, Simultaneous, and
Successive (PASS) cognitive processes of individuals between the ages of 5 and 17 years. The Basic CAS battery includes 8 subtests viz. Matching Numbers (MN), Planned Codes (PCd), Expressive Attention (EA), Number Detection (ND), Nonverbal Matrices (NvM), Verbal-spatial Relations (VSR), Word Series (WS), and Sentence Repetition (SR). These eight subtests tap four cognitive processes called Planning, Attention, Simultaneous and Successive processing.

5. Wide Range Achievement Test-4- The fourth version of Wide Range Achievement Test (Wilkinson & Robertson, 2006) includes 5 subtests i.e., Word Reading, Sentence Comprehension, Spelling, and Overall Achievement. Additionally, Reading Composite is also taken as sum of standardised score of Word Reading and Sentence Comprehension.

6. Mathematical Ability Test- It was developed on the pattern of Fuchs et al.’s (2003) Math Fact Fluency test and Algorithmic computation test. Two separate tests were developed for 6th and 7th grades, each comprising 20 items relating various mathematical problems.

**Analyses**

The obtained data were treated statistically for Analysis of Variance, Pearson’s product moment correlation, multiple regression, and discriminant function analysis.

**Main Findings**

The main findings of the study may be summarised as under:

1. Expectedly, Low Mathematical Ability children have been found significantly lower than their normal counterparts in all the three measures of Working Memory Capacity, viz. Reading Span (F=15.28, p<.001), Operation Span (F=12.57, p<.0001), and Counting Span (F=91.13, p<.001). Hypothesis 1 got supported.
2. Low Mathematical Ability children scored significantly lower on three of the 4 PASS cognitive processes, i.e., Planning (F=8.20, p<.01), Simultaneous Processing (F=17.98, p<.001) and Successive Processing (F=17.54, p<.001). However, low and normal ability children scored almost the same on Attention (F=1.54, p=.22, n.s.). The findings support hypothesis 2.

3. Low Mathematical Ability children have shown greater degree of deficits in 4 of the 5 achievement areas. Serious deficit was recorded in Sentence Comprehension (F=51.00, p<.001), Spelling (F=16.31, p<.001), Reading Composite (F=10.52, p<.001) and Overall Achievement (F= 25.10, p<.001). Deficit in Word Reading was negligible, hence found to be non-significant (F=2.19, p=.14, n.s.). Hypothesis 3 stands accepted.

4. Among the measures of Working Memory Capacity, Reading Span has been found substantially related (reverse) with all the 5 areas of achievement deficit in LMA children. These are Word Reading (r= -.42, p<.001), Sentence Comprehension (r= -.32, p<.001), Spelling (r= -.36, p<.001), Overall Achievement (r= -.49, p<.001) and Reading Composite (r = -.42, p<.001). Whereas Operation Span has shown a considerable degree of negative association with achievement deficit in Word Reading (r= -.40, p<.001), Overall Achievement (r= -.40, p<.001) and Reading Composite (r= -.42, p<.001) and at modest level with Sentence Comprehension (r= -.25, p<.01). Counting Span has been found correlated with achievement deficits at a lower degree as compared to other two measures of working memory. It correlated significantly with Word Reading (r= -.29, p<.001), Sentence Comprehension (r= -.29, p<.001), Spelling (r= -.29, p<.001), Overall Achievement (r= -.39, p<.001) and Reading Composite deficits (r= -.30, p<.001). These results suggest that higher the Working memory, lesser is the achievement deficit. Findings support hypothesis 4 in respect of working memory capacity.
5. In tune with hypothesis 5, findings of the study show relatively strong association between PASS cognitive processes and achievement deficit in low mathematical ability children. All the four PASS processes correlate -.31 to -.42 (all p's <.001) with Overall Achievement deficits and these from -.32 to -.38 (p<.001) with Sentence Comprehension measure of achievement. However, the correlations between PASS cognitive processes and Word Reading, and Spelling are relatively low, though most of them are significant ranging between -.18 and -.37 (p<.05). It means that PASS cognitive processes have relatively weakly association with achievement deficit as compared to working memory.

6. The question whether PASS cognitive processes and working memory jointly contribute to the prediction of achievement deficit in LMA children got answered in affirmative. The measures of PASS cognitive processes and working memory contributed a multiple correlation of .69 suggesting that about 47 percent of the variance in Overall achievement deficit is accounted for by PASS processes and Working Memory. Reading Span, Operation Span among measures of working memory and Planning, Attention and successive processing emerged as strongest predictors of Overall Achievement deficit. Further, Multiple regression for the Reading Composite deficit yielded a multiple correlation of .60 which revealed that 36 percent of variance is accounted for by the measures of working memory and PASS processes. In this case, Reading Span, Operation Span and planning processes have contributed strongly in the prediction of Reading composite. The deficits in spelling was best predicted by reading span and planning processes. The multiple R being .50, twenty-five percent of the variance was accounted for by working memory and PASS processes.

7. Results of discriminant function analysis revealed that PASS cognitive
processes, Working Memory and Achievement deficit are the sources of marked differentiation between Low and Normal Mathematical Ability groups. The overall Wilks’ Lambda value of .71 ($\chi^2= 97.33$, $p<.0001$) suggests that, in overall, the three domains of behavioural competency differentiate between LMA and NMA cases with a success of 65 % for low mathematical ability and 77.7 percent for normal mathematical ability. Standardised Discriminant coefficients showed that Successive Processing, Counting Span, and Sentence Comprehension were the strongest contributors to the discrimination between low and normal mathematical ability children.

In sum, findings of the study suggest that young children with low mathematical ability do not have achievement deficit only, rather they are found lower in intellectual abilities tapped by PASS cognitive processes and the working memory capacities. However, a point of more theoretical importance be further probed through future researches pertains to comorbidity between mathematical disability and achievement deficit, if any. The present data speak unequivocally about potential role of PASS cognitive processes and working memory in the achievement deficits of children with low mathematical ability. In general, findings of the study provide ample support to some of the assertions and predictions put forward by earlier researches (e.g., Kroesbergen et al., 2003; Iglesias-Sarmiento & Deano, 2011).