METHODOLOGY

The present study was aimed at studying the role of working memory, PASS cognitive processes and achievement deficits in children with low mathematical ability. The methodology used to achieve this main research objective is described as under:

Research Design

Since the study required identification of low mathematical ability children from general schools, it was thought advisable to have one group of normal mathematical ability for the purpose of comparison. Therefore, the study involved two non-equivalent comparison groups design. The subjects who scored below 25th percentile on mathematical test were placed in low mathematical ability group (target group) and those who scored above 40th percentile were placed in normal mathematical ability group (comparable group).

Sample

Initially, eleven high schools drawn from three districts of Haryana i.e. Ambala, Bhiwani and Kurukshetra, were surveyed for the identification of low mathematical ability children. A total of 840 students in the age range of 10 to 12 years (6th and 7th grade) were tested on a twenty-item Mathematical Achievement 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.

**Measuring Instruments**

The brief description the measuring instruments used in the study is as under:

1. **Working Memory Tests**

   (a) **Operation Span Test**

   The operation span task is a subtest of working memory designed by Turner and Engle (1989). In operation span task the processing and verification of arithmetic problems was conducted. This subtest consists of series of operation-word strings presented in different sizes. The subject receives a series of simple arithmetic problems in printed form (operation) 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 expected 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. For example, in the following set size of three operation-word string, the subject would read aloud “Is (9 ÷ 3) + 8 = 12? The subject would answer “yes” if the equation was correct or “no” if the equation was incorrect and then would read aloud the word “Ship”. On hearing the word "ship" the experimenter would present the next string. This procedure allows adequate time for each individual to process the operation and word but serves to reduce the time for rehearsal. After the last operation-word string in the set, in this case the third string, the participant would see a set of three question marks centered on the paper sheet. The question marks cued participants to write down the words that followed the operation strings in correct serial order.
For example:

a) Is \((9 \div 3) + 8 = 12\)? SHIP
b) Is \((8 - 4) \times 2 = 8\)? BOAT
c) Is \((3 \times 8) - 3 = 21\)? KITE

? ? ?

The number of operation-word strings (set size) presented before the recall cue varied from two to five, with three trials of each set size. Set size varied in the same randomly chosen order for each participant. Thus the participant could not know the number of words to be recalled until the question marks appeared. The operation span score was the cumulative number of words recalled from perfectly recalled trials.

**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 they are supposed to recall the words that followed the sentences the same way. Subject is to remember unrelated words printed at the end of the sentence. For example, in the following set of three sentences, subject was shown one sentence at a time on the card. He read the sentence aloud and then read aloud the word in capital letters. At that point, the experimenter presents the next sentence. After the last sentence in each set, the participant saw the question marks, which served as a cue that the participant should recall the capitalized words in the correct serial order.

a) They rolled over and one fell down. STORM
b) The king was riding in a rainy night through a street. WRAP
c) Beyond the mountains, some miles away, a lion lives in a cave. CLAY

? ? ?
The number of sentence-word combinations (set size) presented before the recall cue varied from two to five, with three trials of each set size. Set size varied in the same randomly chosen order for each participant. After recalling the words, participants were asked a comprehension question about one of the sentences. Chosen at random, such as “who lives in cave?” The comprehension questions were used to ensure that participants attended to the sentence. The reading span score was the cumulative number of words recalled from perfectly recalled trials.

(c) Counting Span Test

The counting span test of working memory was designed by Kurland and Goldberg (1982). The test requires subjects 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 experimenter presented the initial display of sheets. Each display consisted of randomly arranged dark blue circles, dark blue squares, and light blue circles on the sheet. Participants counted the number of dark blue circles aloud and repeated the digit corresponding to the final tally. For example, if the display contained three dark circles, the participants would say aloud “one-two-three …three” when the “three” was repeated, the experimenter presents the next display, and counting was to begin immediately. The number of targets per display varied from three to nine, with three trials of each. The number of colour distractors (light blue circles) varied from one to five, and the number of shape distractors (dark blue squares) was one, three, five, seven or nine. After two to eight displays, a recall cue (RECALL) was presented, at which point participant was shown the number of targets in each of the previous displays, in the serial order in which they occurred. It should be noted that the memory component of this task is essentially a digit span task with counting of objects interwoven with “presentation of the digit to be recalled.” The counting span score was the cumulative number of digits recalled from perfectly recalled trials.
2. **Cognitive Assessment System**

The CAS is a multidimensional measure of cognitive processing based on the PASS theory of intelligence (Das & Naglieri, 1997). This instrument is made up of four sub-scales: planning, attention, simultaneous and successive processing. It is applicable for children from age of 5 to 17 years. A standard score is provided for each cognitive process i.e., Planning, Attention, Simultaneous, and Successive processing. **Planning** is a process, in which the child takes decisions, selects strategies and uses them, and evaluates solutions for problems. **Attention** is a process by which the individual has to focus on specific stimuli, while there are also other, less-relevant stimuli present. **Simultaneous processing** asks from the child to integrate several different stimuli into a whole. **Successive processing** is a process by which the child integrates stimuli in a specific order. The internal reliability coefficients are high i.e., .88 for Planning, .88 for Attention, .93 for Simultaneous Processing and .93 for Successive Processing. The progression of scores across ages is measured.

The CAS comprises 12 subtests which may be used in two combinations to obtain PASS Scales and Full Scale scores. One combination, the **Basic Battery**, includes eight subtests. The other combination, the **Standard Battery**, includes all twelve subtests. Basic Battery used in the study includes subtests namely Matching Numbers, Planned Codes, Non-verbal Matrices, Verbal spatial Relations, Expressive Attention, Number Detection, Word Series and Sentence Repetition.

a) Planning Scale: It contains tasks that are relatively easy to perform but require the individual to make a decision or decisions about how to solve novel tasks. The subtests that measure this scale are - Matching Numbers (MN) and Planned Codes (PCd).

i. Matching Numbers- Matching Numbers is a paper-pencil subtest composed of items with eight rows of numbers and six numbers per
row. Two of the six numbers in each row are the same. Numbers increase in digit length from one digit on the first row of Item 1 to seven digits on the eighth row of Item 4. Subject is asked to underline the two numbers in each row that are the same. Each item is timed, with Items 1 through 3 having a 150-second time limit, while Item 4 is allotted 180 seconds. Children of age 8 years and above are administered items 2 through 4.

ii. Planned Codes - The Planned Codes subtest contains two items, each with its own set of codes and particular arrangements of rows and columns. A legend at the top of each page shows a correspondence of letters to specific codes (e.g., A, B, C, and D to OX, XX, OO, and XO, respectively). Just below the legend are seven rows and eight columns of letters without the codes. Subject is asked to fill in the corresponding codes in empty boxes beneath each of the letters. Each item is administered and scored separately. The items differ in the correspondence of letters to codes and the position of the letter on the page. Children of age 8 years and above are allocated 60 seconds per item.

b) Attention Scale: The Attention subtest requires the focus of cognitive activity, detection of a particular stimulus, and inhibition of response to irrelevant competing stimuli. Expressive Attention (EA) and Number Detection (ND) subtests make up the Attention scale.

i. Expressive Attention - Expressive Attention is a subtest designed to measure selectivity and the ability to shift attention. The subtest employs two different sets of items, depending on the age of the child. For children of 8 years of age and older, different stimuli are used but the task requirements are same. On the first item children are asked to read 40 words from the stimulus page. These words are color words and are presented in quasi-random order on the page. In the next item children are asked to name the color of a series of
rectangles that are present in quasi-random order on the page. In the final item the words BLUE, YELLOW, GREEN and RED are printed in a different color ink than the colors the words name. The child is instructed to name the color of ink the word is printed in, rather than to read the word.

ii. Number Detection - Number Detection is a subtest designed to measure selectivity, ability to shift attention, and resistance to distraction. Children are presented a page of numbers and are asked to underline specific numbers that appear at the top of each page. In each item, a condition is set whereby children are required to find a particular stimulus on a page containing many distracters. Children of age 8 years and above are asked to underline the numbers 1, 2 and 3 when they are printed in an outlined typeface. In the next item children are asked to underline the numbers 1, 2 and 3 that now appear in regular typeface, and 4, 5, and 6 when they appear in an outlined typeface. There are 18 rows of 10 numbers with 45 targets (25% targets) in each of the first two items, and 15 rows of 12 numbers in the third and fourth items with a total 45 targets (25% targets) in each item. Children must complete each page working from left to right and top to bottom and may not go back to check the page upon completion.

c) Simultaneous Processing Scale: Tasks in this scale require perception of parts into a single gestalt, understanding of logical-grammatical relationship, and synthesis of parts into integrated groups, which occurs either through examination of the stimuli during the activity or through recall of the stimuli. This scale includes Non-verbal Matrices (NvM) and Verbal-spatial Relations (VSR) subtests.

i. Nonverbal Matrices – It is a 33-item multiple choice subtest. Each item utilizes shapes and geometric elements that are interrelated through spatial or logical organization. Children are required to
decode the relationship among the parts of the item and respond by choosing the best of six options. The Nonverbal Matrices subtest items are composed of a variety of formats including completion of geometric pattern, reasoning by analogy, and spatial visualization.

ii. Verbal-Spatial Relations - It is composed of 27 items that require the comprehension of logical and grammatical descriptions of spatial relationship. Children are presented with items that depict six drawing and a printed question at the bottom of each page. The items involve both objects and shapes that are arranged in a specific spatial configuration. The examiner reads the question aloud and the child is required to select the option that matches the verbal description.

d) Successive Processing Scale: The successive scale subtests require the individual to deal with information that is presented in a specific order and for which the order drives the meaning. The subtests included in this scale are Word Series (WS) and Sentence Repetition (SR).

i. Word Series - It consists of nine single-syllables, high-frequency words such as Book, Car, Cow, Dog, Girl, Key, Man, Shoe, and Wall arranged in different sequence and length to make 27 items that the examiner reads aloud to the child. Each series ranges in length from two to nine words, read at the rate of one word per second. The child is asked to repeat the word in the same order as stated by the examiner. Thus, repetition of the sounds of the word string is required.

ii. Sentence Repetition - It consists of 20 sentences that are read to the child. Each sentence is composed of color words (e.g., “The blue is yellowing”). The subject is required to repeat each sentence exactly as it was presented. Color words are utilized so that the sentences contain little meaning and help reduce the influence of simultaneous
processing. Successful completion of the task demands the appreciation of the sentence syntax.

The sequence of administration of subtests is Planning, Simultaneous Processing, Attention and Successive Processing subtests. It takes 45 minutes to administer the basic battery.

3. **Wide Range Achievement Test – Fourth Version (WRAT-4)**

The Wide Range Achievement Test has been used widely as an objective measure of achievement. Initially developed by Jastak, the fourth version has been revised and prepared by Wilkinson and Robertson, 2006. The latest edition is a comprehensive assessment of academic performance in reading and math i.e. basic academic skills of word reading, sentence comprehension, spelling and math computation. The test is available in alternate forms i.e. Blue from and green form which can be used interchangeably with comparative results. The test includes 4 subtests- Word Reading, Sentence Comprehension, Spelling, and Math Computation. It provides scores on these four subtests and an additional aspect called Reading Composite. It takes approximately 30 to 45 minutes to administer the test on children of age 8 years and above.

a) **Word Reading Subtest**- this subtest examines the ability of subject to accurately pronounce words of varying difficulty i.e., common to uncommon and simple to irregular pronunciation. It consists of 15 letters and 55 words. This subtest also determines the starting point of subject on Sentence comprehension. 7 consecutive incorrect response leads to termination of this subtest (7-rule).

b) **Sentence Comprehension Subtest**- this subtest measures ability to gain meaning from words and to comprehend ideas and information contained in sentences. It consists 50 items falling under 6 starting points determined by Word Reading subtest. 7-rule is used to finish the subtest.
c) Spelling subtest- it assesses ability to encode sounds in written form through use of a dictated spelling format containing both letters (letter writing) and words (spelling). There are 15 letters and 42 words in all. 7-rule is used to end this subtest.

Internal consistency reliability coefficients for WRAT-4, according to age groups yielded fairly values. The reliability of scores ranged from .96 to .97 for Word Reading, .96 to .97 for Sentence comprehension, .98 for Reading Composite and .94 to .95 for Spelling for the age of 10 to 12 years. Also, Word Reading and Sentence Comprehension subtests have high value of alternate form immediate retest reliabilities.

4. Mathematical Achievement Test

This test 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 problems. The test consists of two problems each of addition, subtraction, multiplication and division all with regrouping. Following Jordan and Hanich (2000), seven story problems involving, all the four basic operations were included in the test. Time limit for the test is thirty minutes.

Reliability coefficient of the test was obtained through coefficient alpha. Coefficient alpha on the present sample was .83 and .84, respectively for the 6th grade and 7th grade students. Criterion validity was established with provision examination marks, which was found to be .69 and .71, respectively. Content validity indicated 90% agreement between judges on both the tests.

Administration of the tests

At initial stage, a 20 item mathematical achievement test was applied on all the selected subjects from class 6th and 7th of eleven schools of Ambala, Kurukshetra and Bhiwani. The test was in accordance with math syllabus of respective grades. Then tests were scored and percentiles were calculated.
Participants below 25\textsuperscript{th} percentile were placed in low mathematical ability group (target group) and those who scored above 40\textsuperscript{th} percentile were placed in normal mathematical ability group (comparable group). The testing for identification of target was conducted in small groups comprising 20-25 subjects.

After identification of cases in low and normal mathematical ability groups, further testing of participants was conducted individually in a separate room or laboratory provided by the school for this purpose. The testing sessions were held in an atmosphere where adequate facilities were available for proper sitting and ventilation. The tests were administered strictly in accordance with the instructions specified in the respective test manuals or otherwise described by the test authors. All the three measuring instruments were administered to the subjects in two separate sessions, individually, with each session lasting around 45-55 minutes. In the first session, participants received Wide Range Achievement Test (fourth version) and Working Memory subtests. In second session they received basic battery of Cognitive Assessment System. It was noticed that subjects took approximately 45 to 55 minutes for each session.

The subjects were told that they were part of a scientific study and they have to perform at their best on the three ability tests. They were also told that their scores would be kept confidential, so that they could complete the tests without any fear and hesitation. They were asked consequently to answer carefully and to ensure that all the items are answered and no item is left blank in any of the tests. All the queries made by the subjects during or after the testing were satisfied. The general testing conditions were satisfactory and the procedure was uniform all through.

**Scoring of the Tests**

All the tests, namely Working Memory tests, Cognitive Assessment System and Wide Range Achievement Test-4 were scored following the
procedure prescribed in their respective test manuals or as described by the test authors. The scoring of the three subtest scores of WM, 8 subtest scores and four scale scores of CAS, and 4 subtests of WRAT-4 was accomplished separately.

a) Working Memory: The operation span score was calculated by adding the number of sets recalled in perfect sequence with a minimum essential criterion of at least two perfect recalls out of three trials. The Reading Span score was the cumulative score of sets perfectly recalled in sequence on at least two of three trials. The counting span score was the cumulative number of digits recalled from perfectly recalled trials with a minimum essential criterion of at least two perfect recalls out of three trials.

b) Cognitive Assessment System was scored using the test manual and interpretive handbook. Basic battery, including eight subtests was used and scored. In order to obtain scale scores, subtests were scored and converted into standard scores. Then accordingly, subtest scores were added and scale scores were acquired. For scales Planning (matching numbers, planned codes) and Attention (expressive attention, number detection), ratio score for each item was calculated using the number of correct response and time taken. All the ratio scores were added to obtain raw scores. For the rest of scales i.e., Simultaneous Processing (non-verbal matrices, verbal spatial relation) and Successive Processing (word series, sentence repetition) number of correct response was raw score. Further, raw scores were converted into standard scores according to age as mentioned in manual and finally PASS scale scores were obtained.

c) Wide Range Achievement Test-4 provided scores on 3 subtests i.e. Word Reading, Sentence Comprehension, Spelling and a Reading Composite score. Each Correct response given by participant on respective subtest was given score of 1 and incorrect response was given 0. The scores
were added to get final subtest score. The Reading Composite score was obtained by adding the standard scores of Word Reading and Sentence Comprehension subtests.

The scoring of all measuring instruments provided a total of 15 variables which are listed along with their code names as under:

<table>
<thead>
<tr>
<th>Sr.no.</th>
<th>Measures</th>
<th>Code Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mathematic Ability</td>
<td>MA</td>
</tr>
<tr>
<td>2</td>
<td>Mathematical Level</td>
<td>ML</td>
</tr>
<tr>
<td>3</td>
<td>Reading Span</td>
<td>RS</td>
</tr>
<tr>
<td>4</td>
<td>Operation Span</td>
<td>OS</td>
</tr>
<tr>
<td>5</td>
<td>Counting Span</td>
<td>CS</td>
</tr>
<tr>
<td>6</td>
<td>Word Reading</td>
<td>WR</td>
</tr>
<tr>
<td>7</td>
<td>Sentence Comprehension</td>
<td>SC</td>
</tr>
<tr>
<td>8</td>
<td>Spelling</td>
<td>Sp</td>
</tr>
<tr>
<td>9</td>
<td>Reading Composite</td>
<td>RC</td>
</tr>
<tr>
<td>10</td>
<td>Overall Achievement</td>
<td>OA</td>
</tr>
<tr>
<td>11</td>
<td>Planning</td>
<td>P</td>
</tr>
<tr>
<td>12</td>
<td>Attention</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>Simultaneous Processing</td>
<td>Sim P</td>
</tr>
<tr>
<td>14</td>
<td>Successive Processing</td>
<td>Suc P</td>
</tr>
<tr>
<td>15</td>
<td>Full Scale Score</td>
<td>FS</td>
</tr>
</tbody>
</table>

**Statistical Analyses**

The data obtained were tabulated in a rectangular datasheet and were subjected to various statistical analyses, most pertinent to the objectives of the study, through SPSS 12.10. The analyses were conducted
for descriptive statistics, Pearson's product moment correlation and multiple regression. In order to examine whether the variables under consideration differentiate between low mathematical and normal mathematical ability group, data were further analyzed for Discriminant Function Analyses. The detailed description of pertinent analyses is given in the respective section of the next chapter.