DISCUSSION

The study examined the role of working memory and PASS cognitive processes in predicting achievement deficits among children with low mathematical ability. Apart from this major research objective, some other issues related to the subject were also explored. It was at the focus of study to compare the cognitive profiles of low mathematical ability (LMA) and normal mathematical ability (NMA) children. It was of interest to assess the extent to which overall cognitive profile of the sampled subjects including achievement can successfully differentiate between low and normal mathematical ability groups. An overview of the findings indicates that the data provide ample support to most of the hypotheses stemming from the pertinent theoretical conceptualizations and some of the earlier research findings.

The comparison of cognitive profiles of LMA and NMA groups revealed interesting findings. Children with low mathematical ability were indeed found to show significantly lower scores on all the three measures of working memory, four of the five achievement areas and three of the four PASS cognitive processes. The measures of working memory utilized in the present study mainly tap central executive and phonological loop components of working memory. Therefore, it seems plausible to conclude that the central executive and phonological loop play significant part in performance on mathematical problem solving. Otherwise also, this point is very clear from the angle of theoretical perspective and earlier research findings. Observations in the current study are consistent to some of the earlier findings relating performance in mathematics and central executive (Bull et al., 2008; Geary et al., 2007; Swanson & Beebe-Frankenberger, 2004) and phonological loop (Healy & Nairne, 1985; Logie & Baddeley, 1987).
There is strong evidence supporting the point that verbal central executive capacity influences the performance in mathematics. Bull et al. (1999) observed that children’s mathematical skills were directly related to central executive functioning. However, there exists some inconsistency in the findings of relation between phonological loops. Since phonological working memory may be needed in counting (Healy & Nairne, 1985; Logie & Baddeley, 1987), it has a link with performance in mathematics. However, Bull et al. (1999) did not find the role of phonological loop in mathematics. Krajewski and Schneider (2009) found that young children rely more on the visuo-spatial sketchpad to solve calculations, older children make more use of the phonological loop. Many studies have shown that math disabled children experience malfunctions in their central executive system (Holmes & Adams, 2006; Raghubar et al. 2010).

In agreement with the hypothesis and the observations by Naglieri (2000), low mathematical ability group had a cognitive weakness in planning, simultaneous and successive processing. It is believed that planning is an important cognitive process in mathematics (Naglieri & Das, 1987) along with simultaneous processing. Since successive processing also plays an important role in solving math word problems, low and normal mathematical ability groups differ significantly on this cognitive dimension. Therefore, we may conclude that weakness in PASS cognitive processes, specifically planning, simultaneous and successive processing might be a source of mathematical difficulty among 6th and 7th graders. Kroebergen et al. (2003) also noticed that children with difficulties in learning the basic multiplication facts performed generally low on all the four PASS processes, with no differences between the distinct processes. Even the students having difficulty in the specific area of math performance tend to have deficiency in one or the other cognitive processes. For example, math
difficulty students did not perform well on simultaneous processing and
students with difficulties in the automatization of the basic facts showed
problem with successive processing, planning and attention. Generally,
students who had difficulties in solving math word problems showed
relatively weak attention and successive processing and relatively strong
planning and simultaneous processing.

Broadly, LMA group has demonstrated severe achievement deficit in
two of the basic areas and two composite measures under the scope of
investigation. The LMA group has recorded marked achievement deficits in
sentence comprehension, spelling, reading composite and overall
achievement. In general, the findings of the study support the notion that
mathematical difficulty cases are likely to experience deficits on measures of
mathematics and reading achievement. This finding is consistent with the
previous researches indicating that weakness in number fact knowledge
affects reading and other areas of achievement (e.g., Chong & Siegel, 2008;
Geary, 1993; Jordan 1995). Here, in the present study reading composite is a
WRAT-4 derived standard score for word reading and sentence
comprehension. It is more dependable measure of reading achievement
than its individual subtest scores. It is not surprising that math ability
groups differ significantly on four of five variables, rather it is surprising
that they did not differ on word reading, one of basic achievement area in
respect of mathematics (Vukovic & Siegel, 2010).

The correlational analysis on working memory tasks and
achievement deficits in LMA revealed that deficits in all the five indicators of
achievement are inversely related with working memory. Modest to upper
modest degree of association between these measures indicate that higher
the working memory capacity lower is the achievement deficits.
Interestingly, this association is consistent all through the measures of
achievement, i.e., word reading, sentence comprehension, spelling, reading composite and overall achievement. However, word reading and reading composite were higher in their association with working memory. It is so because the measures of working memory employed in the study predominantly tap the central executive and phonological components. Verbal working memory and skills under the control of central executive appear to be generic to learning and provide building block for reading resulting in better academic skills (Bull et al., 2008). Such an importance of executive function of working memory in achievement also surfaced in a number of recent studies (Blair & Razza, 2007; St Clair-Thompson & Gathercole, 2006). It was observed that inhibitory control aspects of executive functioning were uniquely related to a range of achievement measures. In general, children who are deficient at reading comprehension or at word problems have been found to have low scores on the measures of central executive component of working memory. This way central executive aspect of working memory is predictive of word reading, verbal comprehension and acquisition of general academic learning.

The present study found that it is not only central executive which is associated with achievement, it is phonological processing in working memory that also correlates considerably with the performance on WRAT-4 subtests. Some of the recent studies (e.g., Best, Miller & Naglieri, 2011; Cai, Li & Deng, 2011) have also indicated facilitative role of phonological processing in academic related achievement. Therefore, the findings of the present study in agreement with earlier observations in the area of working memory suggest that the phonological loop of working memory also has a significant role in word reading, sentence comprehension and spelling. The working memory tasks of counting span and operation span, employed in the present study, tap the working memory component of phonological
information in the temporary space and help all kind of verbal acquisition where successive processing is actively involved (Cai, Li & Deng, 2011).

The importance of PASS cognitive processes in achievement deficits of low mathematical ability children has unequivocally surfaced in the present study. Without exception, all the four domains of cognitive abilities - planning, attention, simultaneous and successive processing have shown significant negative association with achievement deficits researches carried out within the framework of PASS theory of intelligence have consistently established that all the four cognitive processes tapped by PASS are importantly involved in reading and comprehension (Mahapatra, 2015). In view of Das’s PASS model (Naglieri & Das, 1990) planning is necessary at all levels of reading and its importance increases as a function of complexity of the reading task (Das et al., 2000; Mahapatra & Dash, 1999). Though with little consistency, planning has been found significantly related to reading and comprehension in most of the studies. Studies by Georgiou and Das (2014) and Naglieri and Rojahn (2004) also found positive relationship between planning and reading comprehension. However, the correlation gets stronger when planning includes complex tasks, such as planned composition and syllogistic reasoning. The relationship between attention and the measures of achievement deficit is well understood in the backdrop of PASS model. Attention being the basic prerequisite of all intellectual functions helps the readers to focus on relevant information to the exclusion of the irrelevant ones. It is the functioning of attention to further make way for efficient coding that may be either simultaneous or successive in nature or both. Mahapatra (2015) also observed that process of attention, coding and planning, at conceptual levels, is associated with word reading and reading comprehension.
Results indicating simultaneous and successive processing provide an evidence of their modest, though significant association with achievement deficits. It is interpreted that LMA children having high scores on these two higher cognitive abilities tend to have lower degree of deficit in all the measured areas of achievement- word reading, sentence comprehension, spelling and reading composite. Among the four PASS processes, simultaneous and successive processing are most robust and basic to human intelligence. According to the PASS conceptualization, successive processing influences reading achievement through the effect of phonological reading. The idea is rooted in the way reading develops (e.g., Frith, 1985). It is believed that the beginning of reading development, word recognition is achieved through phonological recoding. Phonological recoding involves the identification of the individual letters in words, retrieval of their corresponding sounds, storing of the sounds in short-term memory and blending of the sounds in serial order. All these steps require successive processing. Similarly, scores on simultaneous processing in children in linked with word reading and comprehension. The PASS theory postulates that simultaneous processing affects reading through the effects of orthographic knowledge (Das et al., 1994). It is believed that apart from requisite successive processing, access to direct visual route is also necessary for efficient word recognition. This is achieved with the use of orthographic knowledge (Barker et al., 1992), which requires phonologically similar letter strings to be compared simultaneously. Wang et al. (2012) also found that effect of simultaneous processing on reading in 3rd to 5th grade children was mediated by orthographic knowledge. Similar to our findings, children with reading deficits have also shown that they were low in successive and simultaneous processing (Das, Janzen & Georgiou, 2007; Deng et al., 2011).
The question at the core of the study was to examine the extent to which achievement deficits could be predicted by working memory and PASS cognitive processes. A linear combination of these predictor variables accounted for substantial proportion of variance in reading composite. Almost thirty six percent of variance in reading composite was accounted for by working memory and PASS processes, and in most part by reading span working memory, operation span working memory and planning process. If we examine the bivariate correlations between predictor and dependent variable, we find other variables also having significant contribution toward reading composite. But regression analysis utilises only the distinctive features of the predictors in accounting for the total variance. However, in the case of spelling achievement only twenty five percent of the variance was accounted for jointly by working memory and PASS processes. The prediction of overall achievement deficit was assessed by taking summated score on all the three subtests- word reading, sentence comprehension and spelling. Findings show that overall achievement deficit was best predicted with the forty seven percent of the variance via significant contribution by reading span working memory, operation span working memory, planning attention and successive processing of PASS processes. With these results, the hypothesis framed in this connection therefore is supported.

These findings need special attention. Firstly, different sets of predictors have been found involved in the prediction of three different indices of achievement deficits. Secondly, in all the three cases reading span working memory and planning cognitive process were the common and potent predictors of achievement deficit. Thirdly, the overall achievement index emerged as major component of individual differences in the achievement of low mathematical ability children. As discussed earlier,
reading span that taps central executive and complex listening element of the working memory plays a crucial role in the prediction of achievement deficits of varying nature. The importance of executive function of working memory in achievement has been highlighted in a number of previous studies (Blair & Razza, 2007; Bull et al., 2008; St Clair-Thompson & Gathercole, 2006).

Although in some of the earlier studies (Best et al., 2011; Naglieri & Rojahn, 2004) planning process did not appear to be significant predictor of word reading, and sentence comprehension. Present data support the ideas put forward by Georgiou and Das (2014). In the case of reading composite, operation span WM has also contributed significantly to its prediction. Operation span measure of working memory tapping phonological loop has played role in reading achievement, which is consistent to the observations of Best et al. (2011) and Cai et al. (2011). Interestingly, three of four PASS processes i.e. planning, attention and successive processing along with the reading span and operation span measures of working memory appeared to be the strongest predictors of deficits in overall achievement. In the light of principles of linear regression, one can understand that despite equally high bivariate correlations with the dependent variable, simultaneous processing did not emerge as significant predictor of achievement deficit. This finding is attributable to the overlap among PASS cognitive processes tapped by CAS (Keith & Kranzler, 1999; Keith, Kranzler & Flanagan, 2001).

Results of discriminant function analysis offer good insight into the cognitive profile of low and normal mathematical ability groups. In overall, significant proportion of variance in distinctive features of low and high mathematical ability groups has been accounted for by the variables in three distinct though related domains – working memory, PASS processes, and achievement. Discriminant function defined by these three domains has
proved its efficiently in discriminating successfully the children of low mathematical ability from those of normal mathematical ability. The analysis being different from multiple regression (a short of combination of ANCOVA and multiple regression) in principle, identified a different set of variables as predictors of group membership. Surprisingly, the most potent variables defining the discriminant function were counting span working memory and sentence comprehension. These two variables being more associated with grouping variables and less associated with other predictor variables played dominant role in discriminating between the groups. Though various studies examining discriminant function values toward group differentiation employed different set of predictor variables, findings of the present study are akin to those reported by Gathercole et al. (2004) and Chan and Ho (2010).

CONCLUSION

In sum, findings of the study suggest that low mathematical ability children recorded severe achievement deficit in sentence comprehension, spelling, and reading composite. The LMA group has been found deficient in central executive and phonological loop function of working memory and three PASS processes viz. planning, simulates, and successive progressive.. The overall achievement deficit among LMA children was best predicted by the reading span and operation span (Working Memory) and planning, attention and successive processing (PASS process). The study offers insight into the need of remediation program for deficient areas of cognitive processing and achievement among LMA children. In view of on going research in such remediation programs, specifically based on PASS model, educational institution and parents should think for the intervention and explore the possibility of improvement in achievement and cognitive deficits.