INTRODUCTION

The field of Learning Disability is a blazing issue with a constantly changing focus. Psychologists, educators, parents as well as government and non-government agencies are showing sensitivity to the issues of children with learning disabilities. There are persistent efforts going on to provide a congenial and flourishing environment for learning disabled. Mental health professionals and psychologists are trying to help children with learning disabilities through assessment, diagnosis and intervention (Sinha, 2014). The unexpected pattern of general strength and specific weaknesses in learning was first noted and studied by physicians during early twentieth century, thus giving the field its historical biometrical orientation (Rijumol, 2015). Although the clinical work conducted during the first half of the twentieth century recognized the existence of learning disabilities, such information had little influence on public school policies until mid-1960s. It was only during the late 1960s and 1970s special education category for learning disability was established.

The term 'Learning Disability' was coined and popularized by Samuel Kirk in the early 1960s and comments that were made at the Conference on ‘Exploration into Problems of the Perceptually Handicapped Child’ at Chicago in 1963. His proposed label was enthusiastically received and helped to unite the participants into an organization known as the Association for Children with Learning Disabilities, the forerunner of today's Learning Disabilities Association (Lerner, 2000). According to Kirk (1963), the term 'learning disabled' is used to describe a group of children who have disorders in development of language, speech, reading, and associated communication skills needed for social interaction. He also made it clear that the term Learning Disabled does not include those children whose primary handicap was generalized mental retardation or sensory impairment like blindness. Therefore specialists like psychologists, and
educationists finally agreed on the educationally oriented term learning disability, and formed an Association for Children with Learning Disabilities (ACLD) in 1964. This way, the notion of learning disabilities as an integrated field came into being. Hallahan and Mercer (2001) summarized the history of learning disabilities and divided this history into five periods: European Foundation Period (1800 to 1920), US Foundation Period (1920 to 1960), Emergent Period (1960 to 1975), Solidification Period (1975 to 1985) and Turbulent Period (1985 to 2000). It has been observed that the major work related to learning disabilities was carried out in the twentieth century except for a few.

The study of learning disabilities was initiated in response to the need to understand individual differences among children who displayed specific deficits in spoken or written language while maintaining integrity in general intellectual functioning. It was an action in response to need to provide services to these students who were not being adequately served by the general educational system. Overall the field of learning disability emerged primarily from the social and educational need. By 1968, specific learning disabilities became a federally designated category of special education. The formal definition offered at that time has not changed substantially and was reaffirmed in the 1977 reauthorization of the Individuals with Disabilities Education Act (IDEA, 1977).

The National Advisory Committee of Handicapped Children (USOE, 1968), headed by Kirk put forward a definition that children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written language. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. They do not include learning problems which are primarily due to visual,
hearing, or motor handicaps, mental retardation, emotional disturbance or environmental deprivation.

The Association for Children with Learning Disabilities (1968) described learning disabled child as a child with adequate mental ability, sensory processes, and emotional stability, which has a limited number of specific deficits in perceptual, integrative or expressive process which severely impair learning efficiency. With only minor changes Kirk's definition was included in Federal Register in 1977. This definition was most commonly used during the 1970-80s and can be stated as: “Specific learning disability means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning disabilities, which are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or of environmental, cultural, or economic disadvantage”.

However, The National Joint Committee for Learning Disabilities (NJCLD, 1990) preferred a slightly different definition. According to it, learning disability is a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of, listening, speaking, reading, writing, reasoning, or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the life span. Problems in self-regulatory behaviors, social perception, and social interaction may exist with learning disabilities but they do not constitute a learning disability by themselves. Although learning disabilities may occur concomitantly with other handicapping conditions (e.g., sensory
impairment, mental retardation, serious emotional disturbance) or with extrinsic influences (e.g., cultural differences, insufficient or inappropriate instruction), they are not the result of those conditions or influences.

The Learning Disabilities Association of America (1986) used the term Specific Learning Disability for LD. Further, specific learning disability is defined as a chronic condition of presumed neurological origin, which selectively interferes with the development, integration, and/or demonstration of verbal and/or nonverbal abilities. Specific learning disabilities exist as a distinct handicapping condition and vary in its manifestations and in degree of severity. Throughout life, the condition can affect self-esteem, education, vocation, socialization, and/or daily living activities.

The DSM-IV TR (APA, 2000) uses the term “learning disorder” that unceremoniously seems to follow the NJCLD definition. Learning disorders are characterized by academic functioning that is substantially below that expected given the person’s chronological age, measured intelligence, and age appropriate education. The specific disorders included in this section are- Reading Disorder, Mathematical Disorder, Disorder of Written Expression, and Learning Disorders not otherwise specified.

The World Health Organization (2001) defined learning disability as a state of arrested or incomplete development of mind. Somebody with a learning disability is said to have significant impairment of intellectual functioning and significant impairment of adaptive or social functioning. This means that the person will have difficulties in understanding, learning and remembering new things, and in generalizing any learning to new situations. Because of these difficulties with learning, the person may have difficulties with a number of social tasks like communication, self-care, awareness of health and safety. A final dimension to the definition is that these impairments are present from childhood, not acquired as a result of accident or following the onset of adult illness. The levels i.e., mild, moderate, severe, and profound may also be used with learning disability.
Although there is a divide between the medical (DSM) and educational (IDEA) definitions of learning disabilities, however most of these definitions present learning disabilities with significant difficulties in specific academic skills but not in normal intelligence. In general, it is described as a significant discrepancy between academic achievement in a specific area or subject and general intelligence, although how large the discrepancy must be for a child or adolescent to qualify as having a learning disorder, is open to interpretation. In addition to academic difficulties, they may have difficulty responding to social cues and may suffer from low self-esteem. In view of these definitions, learning disabilities encompass an extremely heterogeneous group of problems with diverse characteristics that can result from a variety of biological influences including genetic factors, environmental insults to the brain, and extreme lack of early environmental stimulation.

The field of learning disability is multidisciplinary in nature. Opinions about what constitutes a learning disability vary in part because it is the concern of many disciplines and professions, including education, psychology, neurology, neuropsychology, psychiatry, optometry and speech and language psychology, to name a few. Each of these disciplines has traditionally focused on different aspect of the child with learning disability, so divergent ideas about importance of etiology, diagnostic methods, intervention methods and professional's role and responsibilities have to be considered.

A neuropsychological perspective of learning disability provides an understanding of the underlying forces that affect rate and level of achievement across academic domains. It provides an understanding of the reasons why some children struggle academically. An early identification of children at risk for poor learning abilities is critical because children who start kindergarten behind their peers tend to stay behind throughout their schooling (Duncan et al., 2007).
However, Kirk and Kirk (1971) viewed learning disability from a psycholinguistic perspective which proposed that underlying specific deficiencies in central nervous system functioning result in deficits in psycho-neurological learning processes, which in turn, explain observed learning disability. Based on the psycholinguistic process model of Charles Osgood, Kirk described LD according to learning channels (auditory/verbal or visual/motor), learning levels (rote or conceptual), and specific processes (perception, reception, memory, integration, expression etc., Kirk & Kirk, 1971).

The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (APA, 2013) takes a different clinical approach to learning disorders than previous editions by broadening the category to increase diagnostic accuracy and effectively target care. It considers specific learning disorder as a single, overall diagnosis, incorporating deficits that impact academic achievements. Rather than limiting learning disorders to diagnoses particular to reading, mathematics and written expression, the criteria describe shortcomings in general academic skills and provide detailed specifiers for the areas of reading, mathematics, and written expression.

**Prevalence of Learning Disabilities**

As far as prevalence rate of learning disabilities is considered, at first glance it appears to be a relatively straightforward process. However, since there is no consensually accepted definition, the process of determining its prevalence is a quagmire. In recent times, incidence figures for this non-definitive disorder or group of disorders cannot be determined precisely and there are essentially broad estimates (Goldstein, 2011). Depending on the stringency of identification criteria, prevalence estimates for learning disability have varied from as low as 1 percent to as high as 30 percent of the school age population (Lerner, 2000). Mercer and Miller (1992) suggested that those with severe specific learning disability might comprise
approximately 1.5 percent of students, while the inclusions of students with mild learning disability could raise that figure to about 4-5 percent (National Health Interview Survey, 2003). Other studies focusing on specific classification of LD indicate that from 5-8 percent of school age children exhibited arithmetical disabilities (Geary, 2003) and 5 to 17.5 percent were dyslexic (Shaywitz, 1998).

The DSM-5 cites prevalence of Learning Disorders from 2 percent to 10 percent depending upon the nature of ascertainment and definitions applied. Approximately five percent of students in public schools in United States have been identified as having a learning disorder. Prevalence of reading disorder is estimated at 4 percent in school age children in United States. The prevalence of mathematical disorder alone has been estimated at approximately one in every five cases of learning disorder. It is estimated that 1 percent of school age children have mathematics disorder. Disorder of written expression is rare when not associated with other learning disorders.

Research efforts to identify early indicators of LD in basic reading skills have concluded that virtually all children scoring below the 25th percentile on standardized reading tests can meet the criteria for having a reading disorder. In written expression researchers estimate its true prevalence in between 8 percent and 15 percent for the school population. Research also indicates that approximately 6 percent of the school population has difficulties in mathematics which cannot be attributed to low intelligence, sensory deficits or economic deprivation. On the basis of long term studies and many small scale studies, Geary (2010) concluded that about 7 percent of children and adolescents will be diagnosable as mathematical learning disabled, in at least one area of mathematics.

In India, there has been an increasing awareness and identification of learning disabled children during the last decade or two. Despite this growing interest, there is still no clear idea about the incidence and
prevalence of learning disability. Epidemiological studies of LD are fraught with difficulties ranging from the very definition, identification and assessment, to socio-cultural factors unique to India. The Federal definition implies key factors as adequate intelligence, appropriate instruction and socio-cultural factors. The implications of these terms for identification of children with learning disability in a pluralistic society such as ours are immense and cannot be easily handled (Karanth, 2002). An epidemiological study was done by the Department Of Psychiatry, Epidemiology and Biostatistics from 1995 to 2000 at NIMHANS in urban and rural areas of Bangalore to determine prevalence rates of child related and adolescence psychiatric disorders for the Indian Council of Medical Research. The total prevalence rate in 4-16 year old children in urban middle class, slum and rural areas was found to be 12 percent.

A study at the L.T.M.G. Hospital, Mumbai indicated that 29 percent of total children visiting the hospital for certification of any kind of disability were diagnosed as having a specific learning disability. These children came from the lower, middle and upper middle socioeconomic strata of society. Studies conducted by the Sree Chithira Thirunal Institute of Medical Sciences and Technology in Kerala in 1997 revealed that nearly 10 percent of the children population has developmental language disorders of one type or the other and 8-10 percent of the school population has learning disability of one form or the other. Screening for Learning Disabilities for Classes I to VII in schools with follow-up assessments by experts in 10 panchayats in Kerala revealed that 16 percent of these school children have a learning disability (Suresh, 1999). Other studies conducted at child guidance clinics in India (John & Kapur, 1992; Kapur, 1985; Khurana, 1980) found 20 percent children attending the clinic to be scholastically backward.

**Types of Learning Disabilities**

While considering the types of learning disabilities, there are 2 parallel yet overlapping points of view which mention different types of
learning disability. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM IV-TR; APA, 2000) there are four academic skill disorders under the category of Learning Disorders which are—Reading Disorder, Mathematical disorder, Disorder of Written Expression and Learning Disorder Not Otherwise Specified. All of these are based on age, intelligence, and educational experience of the child, and interfere with child’s academic performance or activities of daily living. The description is as under:

a) Reading Disorder: The essential feature of RD is reading achievement (i.e. reading accuracy, speed or comprehension as measured by individually administered standardized tests) that falls substantially below that expected given the individual’s chronological age, measured intelligence and age appropriate education. The disturbance in reading significantly interferes with academic achievement and activities of daily living that require reading skills. Mathematical disorder and disorder of written expression are commonly associated with RD. Four percent of school-going children suffer from this disorder.

b) Disorder of Written Expression: When individual falls substantially below in writing skills given the individual’s chronological age, measured intelligence and age appropriate education. The individual is said to suffer from disorder of written expression. It interferes with academic achievements or with activities of daily living that require writing skills. This disorder is seldom diagnosed before the end of first grade.

c) Mathematics Disorder: The essential feature of Mathematics Disorder is mathematical ability (Mathematical Calculation and reasoning) that falls substantially below that expected for the individual’s chronological age, measured intelligence and age appropriate education. The disturbance in mathematic significantly interferes with academic achievement or with activities of daily living that require
mathematical skills. A number of different skills may be impaired in mathematics disorder, including linguistic skills (e.g., understanding or naming in mathematical terms, operations or concepts and decoding written problems into mathematical symbols), perceptual skills (e.g., recognizing or reading numerical symbols or arithmetic signs and clustering objects into groups), attention skills (e.g., copying numbers, figures correctly, remembering to add in ‘carried’ numbers and observing operational signs), and mathematical skills (e.g., following sequences of mathematical steps, counting objects, and learning multiplication tables). It is estimated that 1 percent of school age children have mathematical disorder.

d) Learning Disorder, Not Otherwise Specified: The main feature of this disorder is that individual is diagnosed with a learning disorder that is not specified as a reading, writing, or mathematics disorder, due to the presence of a combination of reading, writing, or maths difficulties. These difficulties are most often symptoms of processing deficits. It may include deficits in auditory processing, visual processing, speed of processing, or any combination of these. These processing difficulties make learning information difficult and impact all learning activities.

However, DSM-5 (APA, 2013) used a common umbrella term ‘Specific Learning Disorder’ or SLD. It is viewed as difficulty in learning and using academic skills. Diagnostic criteria include difficulty with word-reading, understanding the meaning of what is being read, word meaning, spelling, written expression, number use, calculation, and mathematical reasoning. DSM-5 combines the diagnoses of reading disorder, disorder of written expression, mathematics disorder, and learning disorder not otherwise specified which were separate in DSM-IV. It determines academic performance through standardized achievement measures and comprehensive clinical assessment.
Another school of thinking which describes different kinds of learning disabilities considers the educational basis of learning disabilities rather than clinical point of view. According to this, 3 broad types of specific learning disabilities are:

a) Dyslexia: A specific learning disability that affects reading and related language-based processing skills. The severity can differ in each individual but can affect reading fluency; decoding, reading comprehension, recall, writing, spelling, and sometimes speech and can exist along with other related disorders. Dyslexia is sometimes referred to as a Language-Based Learning Disability.

b) Dysgraphia: A specific learning disability that affects a person's handwriting ability and fine motor skills. Problems may include illegible handwriting, inconsistent spacing, poor spatial planning on paper, poor spelling, and difficulty composing writing as well as thinking and writing at the same time.

c) Dyscalculia: A specific learning disability that affects a person's ability to understand numbers and learn math facts. Individuals with this type may also have poor comprehension of math symbols; may struggle with memorizing and organizing numbers; have difficulty telling time; or have trouble with counting.

d) Co-existing Disorders: These provide valuable insight into the individual needs of a child and the subsequent intervention planning. The most common co-existing disorders are dyspraxia, disorder of executive functioning, Attention Deficit Hyperactivity Disorder (ADHD), auditory processing disorder, visual perceptual or visual motor deficit and non-verbal learning disabilities.

**Mathematical Learning Disability**

Mathematical learning disability abbreviated as MLD (Geary, 2011) is considered to be the same construct as mathematics disorder (APA, 1994),
developmental dyscalculia (Butterworth, 2010), and specific arithmetic difficulties (Lewis et al., 1994). All terms refer to the cases where poor mathematical performance is combined with at least average intelligence. Identifying qualitative discontinuities or biological markers for MLD would enable researchers to escape the arbitrariness of purely statistical criteria, but these have yet to be discovered.

MLD has been identified on the basis of math performance below the 16th percentile (e.g., De Smedt & Gilmore, 2011; Landerl et al., 2009) but some consensus is emerging in defining MLD as scores below the 11th percentile, identifying scores between the 11th and 25th percentiles as low average or low mathematical achievement (LMA) and treating any scores above the 25th percentile as typical achievement (TA, Geary, Hoard et al., 2012; Mazzocco et al., 2011). Five to ten percent of children and adolescents of school age are identified as low ability individuals (Berch & Mazzocco, 2007; Geary et al., 2007). Relative to Typical Achieving children, children with mathematical disabilities have severe and persistent deficits in the ability to develop long-term memory representations of basic arithmetic facts or retrieve them once they are learned. They remember fewer facts and when they retrieve the facts, they commit more errors and especially more atypical errors, such as $5 \times 4 = 40$. These children also have delays in the development of procedures for solving arithmetic problems. Many of these children eventually learn basic procedures but are one to several years behind their peers. The magnitude of this deficit and the extent of the delay appear to vary with the complexity (e.g., number of steps) of the procedure. Although low mathematical ability children may not fully close the achievement gap, their competencies become more similar to normal children than to children with MLD across grades (Chong & Siegel, 2008; Mazzocco et al., 2008).

In order to get clarity about mathematical disability, it is important to know the basic components of mathematical ability. Mathematical ability
includes knowledge of arithmetical facts, understanding and using math principles, estimation, applying arithmetic to the solution of word problems, forming a number sentence and carrying out mathematical procedures-calculation etc. Some of the common areas which create mathematical disabilities are memory for arithmetical facts, exclusive reliance on cumbersome counting strategies, word problem solving, representation of place value and the ability to solve multi-step arithmetic problems.

Children identified as a manifesting LD in mathematics can demonstrate deficits in arithmetic calculation, mathematical reasoning, or both. In general authorities agree that 6 percent of school population has difficulties in mathematics that cannot be attributed to low intelligence, sensory deficits or economic deprivation. It appears that deficits in arithmetic calculation skills are more frequently identified than deficits in arithmetic reasoning.

Cognitive studies of children with mathematical learning disability and low mathematical ability children have largely focused on number, counting and arithmetic, and are supplemented by neuropsychological studies of developmental dyscalculia (Butterworth, 2005; Butterworth & Reigosa, 2007). The proposed mechanism underlying cognitive patterns range from fundamental deficit in potentially inherent number and magnitude representational systems (Butterworth, 2005) to domain general deficits in working memory that make the learning of mathematics and other academic domains in school difficult (Swanson & Sachse Lee, 2001).

Apart from these, a deficit in a fundamental magnitude representational system can affect the learning of mathematical content that is dependent on understanding of numerical magnitude. This deficit leads many small things at one time to cascade into many or all of the number, counting and arithmetic deficits that have been identified in children with mathematical disabilities and to a lesser extent in low ability children. Fundamental difficulties in understanding magnitude are very different
from mathematical cognition deficits that result from below average working memory capacity. Thus studies aimed at identifying these mechanisms are critical to the advancement of the field.

Butterworth and colleagues (2007) have proposed that Dyscalculia and presumably mathematical disabilities results from deficits in two fundamental number sense systems, one that supports the representation and implicit understanding of the exact quantity of small collection of objects and of symbols (e.g., Arabic numerals) that represent these quantities, and the other for representing the approximate magnitude of larger quantities (Butterworth & Reigosa, 2007). In keeping with Butterworth's (2005) hypothesis, children with MLD and to a lesser extent, low ability children may have deficits or developmental delays for both subsidizing and the ability to represent approximate quantities (Geary et al., 2008).

Most children are believed to learn counting by rote memory and this in itself is not a useful indicator of MLD or LA status. Research in this area has focused on whether these children understand the core principles of counting. Gelman and Gallistel (1978) proposed that children’s counting behavior is guided by five inherent and implicit principles that mature during preschool years which are principle of one-one correspondence, stable order, and cardinality of how to count rules that in turn provide the potentially inherent structure for children’s emerging counting knowledge. Elementary school children with mathematical disabilities and low ability understand most basic principles, but are sometimes confused when counting deviates from the standard left to right counting of adjacent objects.

By the time they enter kindergarten, children have coordinated their number knowledge and counting skills with an implicit understanding of addition and subtraction, using number words to solve formal addition and subtraction problems. Children use a mix of problem solving strategies like
finger counting strategy, verbal counting strategy, min and sum procedure and max procedure etc. Direct retrieval from long term memory enables children to answer spontaneously. At any time children use any of the many strategies to solve problems.

It is believed that the causes for dyscalculia are deficits in long term semantic memory and in two aspects of working memory, speed of processing and rate of decay of items being retained (Geary, 1993). The role of long term semantic memory is premised on the idea that there is a developmental progression from calculation strategies, such as counting, to established associations between problems and their solutions. According to Geary, laying down these associations in long term memory depends on maintaining the problem elements (for example two addends, intermediate results and solution) in working memory. Additionally the use of immature or inefficient calculation strategies will risk decay of crucial information in working memory.

Later in 2007, Geary and colleagues found that low mathematical ability (LMA) children have average scores on measures of phonological loop and visuospatial sketchpad. McLean and Hitch (1999) compared a group of LMA children to age and ability matched controls and found evidence that the LMA children had deficits in the task switching component of the central executive. Many low math ability children appeared to have a normal phonological working memory especially if reading achievement was average or better and a normal ability to use the attentional control functions of central executive to maintain information in working memory. The most promising results suggested that low ability children had subtle deficits in the inhibitory control and task switching components of the central executive.

As with other forms of learning disability, twin and family studies reveal genetic and environmental contributions to individual differences in mathematical achievement and to mathematical learning disability and low
ability (Shalev et al., 2001). Shalev and her colleagues found that family member of children with MLD are ten times more likely to be diagnosed with MLD than are individuals in the general population. The genetic influences responsible for the low performance associated with MLD, whether defined as below the 5th percentile or the 15th were responsible for individual differences at all levels of performance (Kovas et al., 2007). These results suggest there are not specific MLD genes, but rather the genetic influence on mathematical achievement across the continuum of scores.

Mathematical difficulties are not just an education related concern. Research has repeatedly demonstrated that mathematical competence is important for success not only in school, but also has an impact on future employment, income levels, and work productivity. As children progress through school, mathematics competency is critical not just for academic performance, but also for daily living skills such as earning an income, budgeting, and knowing appropriate ways to spend money. With advent of new researches and techniques, hope is that it will be easy to understand mathematical as well as other forms of learning disabilities so that effective and innovative intervention can be developed for learning disabled.

Achievement Deficits

In modern times academic achievement is believed to be a key criterion to judge one's total potential and capability. Thus it occupies a very important place in education as well as in the learning process. This might be the reason that it is being considered as one of the most important goals of the educational process. It is one of those goals at which every individual is expected to perform irrespective of cultures. Academic achievement is a key mechanism, through which student realise their talents, abilities and competencies which are an important part of developing career aspirations (Lent, Brown, & Hackett, 2000). Assessing student's progress means identifying what he has achieved. Acquiring skills in academic matters is important as a means of attaining complete realization.
In his pioneering work, Henry H. Murray (1938) devised a taxonomy that included 20 basic human needs. Out of these needs, he conceived one as the desire to accomplish something difficult which was called achievement. Achievement was considered as desire to master, manipulate or organize physical objects, human beings or ideas as rapidly and independently as possible. Further, it was considered that these desires are accompanied by actions like making intense prolonged and repeated efforts to accomplish something difficult; working with singleness of purpose towards a high and distant goal, having the determination to win.

Though achievement was effectively described through conceptualization of Murray, yet the term ‘academic achievement’ differs from the very concept of achievement. Academic achievement is a broad term which is basically the outcome of education. It is the extent to which a student, teacher or institution has achieved their educational goals. Academic achievement is commonly measured by examinations or continuous assessment but there is no general agreement on how it is best tested or which aspects are most important. For assessment of achievement, various methods are designed like individual achievement against a specific achievement norm (e.g., achievement batteries), achievement quotients, and intelligence tests.

Crow (1969) defined Academic achievement as the extent to which a learner is profiting from instructions in the given area of learning i.e. achievement is reflected by the level to which skill and knowledge has been imparted to him. Academic achievement also indicates the knowledge attained and skill developed in the school subject, generally designated by test scores. According to Good and Power (1976), the knowledge attained or skills developed in school subjects are usually developed by teachers. It is considered as an accomplishment or proficiency of performance in a given skill or body of knowledge. The Dictionary of Psychology (Atkinson, Berne, & Woodworth, 1988) defines achievement as a specified level of proficiency in scholastic or academic work.
It is believed that academic achievement affects three major areas of behaviour i.e. cognitive, affective and conative. Therefore it is difficult to say without proper evidence that pupils reach at the same level in all the three dimensions at the same time. Pupils may be at a somewhat higher level in one domain and at somewhat lower level in the other domain. This means pupils may be at different levels of achievement in different areas.

In a survey by Carnegie Council of Adolescent Development (1989), it was revealed that about one-quarter of the adolescent population is at risk of academic failure and other behavioural problems, with another quarter considered moderately at risk. Researchers have identified numerous factors that are associated with academic success or failure. These range from individual aspects of learning, behavioral problems or cognitive deficiencies to family factor such as parenting techniques to social issues such as poverty and cultural differences.

Poor self-concept and low sense of control lead to poor academic performance and vice-versa. Research evidence shows high correlation between self-concept and school achievement. Behavioral problems in school, starting in the elementary grades are associated with low academic achievement. Aggression (Lambert et al., 1989) and hyperactivity have been studied and found to have correlation with low academic achievement. Students from low SES are more likely to lack in basic academic skills and achievement. Children of poor parents are at risk for poorer health and nutrition that could affect their ability to concentrate in the classroom. Lack of social support by parents may affect school achievement.

Sometimes it is observed that students with average intelligence perform poorly on achievement tests. Sometimes it may be explained on the basis of situational factors whereas there might be presence of achievement deficits in such children as well. Achievement deficits can be commonly referred to as the low performance of students on achievement measures when this poor performance cannot be explained due to intellectual
deficiency. Some of the major domains of achievement deficits are reading deficits, spelling deficits, comprehension deficits, writing deficits, deficits in expression and mathematical deficits which may exist in combination or on their own.

The widely accepted practice of determining academic achievement is in the terms of performance of students on testing measures. Past researches show two general patterns of measuring achievement deficits. The first method is to consider the low scores on standardized achievement tests as achievement deficits whereas the second method consists of a refined statistical method i.e. to use the deviation score as an index of achievement deficit. The later method can be assumed to be based on the concept that deficit generally show the deviation from the normal range of achievement. Therefore it can be concluded that children with achievement deficits are present at the mediating level between the normal and learning disabled children which may show deficits in academic as well as life related skills.

**Working Memory**

Working memory is a dynamic and evolving area of psychological research. It is considered to be a crucial concept in cognitive psychology and neuroscience (Baddeley & Hitch, 1974). It refers to the central structures and processes that temporarily maintain, store and manipulate information for supporting human thought process. Working memory is a limited capacity system that permits a limited amount of information active for a brief period of time and operates on it. In particular, working memory permits to temporarily maintain task relevant information during performance of complex cognitive tasks that require willingness, awareness and attention such as reasoning, planning, manipulation of linguistic information, and executive control and coordination of perception and action in complex cognitive operations.
In cognitive psychology, working memory refers to a limited capacity system allowing a temporary storage and manipulation of information necessary for such complex tasks as comprehension, learning and reasoning. The key feature of working memory is its capacity, both, to store and manipulate information. Working memory functions as a mental workspace that can be flexibly used to support everyday cognitive activities that require both processing and storage such as for mental arithmetic. However, the capacity of working memory is limited and the imposition of either excess storage or processing demands in the course of an ongoing cognitive activity will lead to catastrophic loss of information from this temporary memory system. In comparison to WM, short term memory refers to the capacity of storing units of information, and is typically assessed by serial recall tasks involving arbitrary verbal elements such as digits or words.

**Models of Working Memory**

A variety of models and theories have been proposed to provide clarity to the concept of working memory. Some of these served as foundation while others are considered as modern approach to the concept. Viewing alternative approaches to working memory seems to be healthy because it is through contrasts that research can be focused in a productive way. It facilitates the appreciation of the benefits and drawbacks of looking at memory phenomena from particular vantage points and draws out different aspects of memory phenomena. These include the nature of developmental changes in working memory, the characteristics of memory systems, and the strategies adopted by children to preserve information for future recall.

1. **Baddeley’s Multi-component Model of Working Memory**

   The coherent model of working memory was initially proposed by Baddeley and Hitch (1974) and subsequently modified by Baddeley in 1986. In its original version, Baddeley and Hitch (1974) put forward working
memory as Multi-component system consisting components for different sensory modalities. The component, which is at the vertex is central executive system which is considered being involved in on-line cognitive processing, such as problem solving and calculation. The component interacts with three sub systems, the phonological loop, visuospatial sketchpad, and episodic buffer.

![Diagram of Baddeley's model of working memory](image)

**Figure: 1 Baddeley's model of working memory (2000)**

According to Baddeley (2000) working memory consists of four components as Central executive, phonological loop, visuospatial sketchpad and episodic buffer. The Central Executive is responsible for the high level control and coordination of the flow of information through working memory, including the temporary activation of long term memory. It has also been linked with control processes such as switching, updating and inhibition (Baddeley, 1996). The central executive is supplemented by two slave systems specialized for storage of information within specific domains. The phonological loop provides temporary storage for linguistic material and the visuospatial sketchpad stores information that can be represented in terms of visual or spatial structures. The fourth component is the episodic buffer which is responsible for integrating information from different
components of working memory and long-term memory into unitary episodic representations (Baddeley, 2000). This model of working memory has been supported by evidences from studies on children (e.g., Alloway, Gathercole et al., 2004; Alloway, Gathercole, & Pickering, 2006), adult participants, neuropsychological patients (e.g., Gathercole & Baddeley, 1993) as well as neuroimaging investigations.

Verbal working memory skills are effective predictors of performance in many complex cognitive activities including reading (e.g., de jong, 1999), mathematics (e.g., Bull & Scerif, 2001) and language comprehension (e.g., Signeuric, Ehrlich et al., 2000) as well as attainments in National curriculum assessment of English and Mathematics (Alloway, Gathercole, Adams, & Willis, 2005). Recent research has also established that poor verbal working memory skills, but not general intelligence or verbal short term memory, are uniquely linked with both reading and mathematical abilities. This asymmetry of associations provides a strong basis for identifying working memory as a specific and significant contributor to general learning disabilities.

According to Alan Baddeley, cognitive psychologists involved over the last two or three decades in developing the concept of working memory theoretical concepts can potentially be useful to practitioners on at least three levels. First, they may provide a broad understanding of the processes underlying practice. Second such an understanding can, in turn, be used to develop better methods of assessment that will allow teaching or remedial strategies to be optimally targeted. Third, the concepts may contribute to a better understanding of the whole process of teaching and in due course, help to improve educational methods more generally.

While observing key aspects of Baddeley’s model of working memory, it appears what has been proposed is a multi-component architecture based on storage systems that are tied to particular domains and controlled by an executive system. Working memory components interact yet they also have
considerable independence. Verbal memory is heavily linked to articulation and rehearsal activities, although it is also clear that this is not the complete story. The development of working memory involves qualitative changes in the way that information is remembered as well as quantitative changes arising from the efficiency of rehearsal and speed related processes. The executive system is a complex controlling device, which has been given responsibility for a variety of cognitive tasks. Given the degree to which representations are used in mental activities, working memory is an important contributor to many cognitive phenomena.

2. Cowan’s Embedded Processes Model

Cowan’s model of working memory is an ‘embedded processes’ model that consists of (1) central executive, (2) long-term memory, (3) active memory: subset of memory in a temporarily heightened state of activation, and (4) the focus of attention. Cowan (1999) model is inherently hierarchical in its structure. The model has three levels and the distinctions between them are more marked. Long term representations make the first level of memory. Activated long-term memory representations form a second level of memory and these are subset of the first level. These representations are in a more accessible state than the full set of memory representations. The focus of attention, a subset of activated representations, forms third level of mental process. Baddeley’s (2000) notion of episodic buffer as a fourth component of working memory brings the two models somewhat closer, in that this episodic buffer lies between the two slave systems, being the place where modality based representations are extracted and become integrated and the central executive which controls the operation.

Cowan’s vision of working memory is that it is a collective term referring to the set of mental processes that result in representations being available in unusually accessible state. The level of accessibility is important because the representations can influence how any task with a mental
component is carried out. Memories are not effective in shaping mental contents. It is only when these memories are accessible through increased activation, that they can achieve this. Activated representations are not just free floating, independent and unconnected. Features need to be bound together and there need to be some way to recover the temporal sequence in which events take place and to mark other episodic information (e.g., which elements were activated after others). This contextual information also forms part of working memory. Such bindings are thought to occur only when representations are in the focus of attention, and once established the links rapidly become incorporated within long term memory. Hence, the emphasis is on the collective nature of the term working memory, as a set of processes that produce representations which are memorable and can be used in other circumstances.

Figure: 2 Cowan’s Model of Working Memory

According to Cowan et al. (1999), the focus of attention is quite limited. Cowan (2001) argued that the average capacity of the focus of attention for normal adults is about four unconnected chunks. This seems to be a revision of Miller's (1956) magic number seven, or minor adjustment of
Broadbent’s (1975) capacity estimate of three chunks. This limited capacity may be rooted in the nature of memory representations. Any information that is deliberately recalled is restricted to this limit in the focus of attention and only the information in the focus is available to conscious awareness (Cowan 2001). As the focus of attention is capacity-limited, if information exceeds the capacity the earlier items in the focus have a higher chance of being deactivated and displaced from the focus of attention (Haarman & Usher, 2001). Like Baddeley, Cowan’s model emphasizes the links between memory and attentional functioning. The focus of attention is capacity limited whereas activation is time limited and is also susceptible to interference.

3. Biologically Based Computational Model of Working Memory

O’Reilly, Randall, Braver and Cohen (1999) proposed working memory as controlled processing involving active maintenance and rapid learning, where controlled processing is an emergent property of the dynamic interactions of multiple brain systems. But the prefrontal cortex (PFC) and hippocampus (HCMP) are especially influential due to their specialized processing abilities and their privileged locations within the processing hierarchy. Both PFC and HCMP are well connected with a wide range of brain areas, allowing them to influence behaviour at a global level. The specific features of their model are: (i) A prefrontal cortex specialized for active maintenance of internal contextual information that is dynamically updated and self-regulated allowing it to control ongoing processing according to maintained information (e.g., goals, instructions partial products etc.), (ii) A hippocampus specialized for rapid learning of arbitrary information, which can be recalled in the service of controlled processing, while the posterior perceptual and motor cortex (PMC) exhibits slow, long term learning that can efficiently represent accumulated knowledge and skills, (iii) Control that emerges from interacting systems (PFC, HCMP and PMC), (iv) The dimensions that define continua of
specialization in different brain systems e.g., robust active maintenance, fast versus slow learning, (v) Integration of biological and computational principles.

This model is still under construction but there is a broad and compelling blueprint for future exploration. This model provides many examples where computational principles are used to understand biological properties, in ways that are consistent with existing ideas in many cases but also can achieve a new level of synthesis and clarity (Shah & Miyake, 1996).

4. Resource Sharing Model

The model proposed by Daneman and Carpenter (1980) postulates existence of a link between storage and processing demands. Working memory tasks measure functional capacity of resources allotted between storage and processing activities (Daneman & Hannon, 2001; Just & Carpenter, 1992). However, Engle et al., (1999) claimed that working memory capacity is determined by STM capacity plus so called controlled attention ability. This ability is conceived as a domain general limited attentional capacity for performing controlled processing or sustaining focus on task relevant information in the face of interfering or distracting stimuli.

Interestingly, Resource sharing model proposes that variance shared between WM and STM tasks should reflect their common short term storage component, whereas the residual working memory variance should reflect the controlled attention or executive component of the WM system. Engle et al. (1999) have proposed that individual differences on measures of WMC primarily reflect the differences in controlled attention capability. The factor underlying measures of WM and higher level cognitive tasks like performance on conventional intelligence tests, is the ability to maintain representation active in the face of interference from automatically activated representations competing for selection, for action, and in the face
of distractions that would otherwise draw attention away from the currently needed representation.

5. Logie's Model

Logie's (1999) theory of working memory suggests that working memory implies a coherent collection of specialized cognitive functions. One group of functions enables temporary storage of visual appearance of objects and scenes (the visual cache), a second group offers temporary retention of verbal material in terms of sounds or phonology (the phonological loop), while a third offers a coordinating executive function, which enables the conscious manipulation of information (central executive). All of the components draw on prior knowledge (the knowledge base) and on the products of moment-to-moment perception (interpreted via the knowledge base). The model as a whole is devised from experimental work with normal adults and children, from studies of individuals who have suffered brain damage, from computational modeling, and from work using brain imaging techniques. A series of illustrations show how the features of the model have been used to explore and account for a range of laboratory and everyday cognitive tasks.

6. Global Workspace Model

The Global Workspace Model (Baars, 1988) is a cognitive architecture with an explicit role for consciousness. It makes seven assumptions: (i) that the brain can be viewed as a collection of distributed specialized networks (processors); (ii) that consciousness is associated with a global workspace in the brain- a fleeting memory capacity whose focal contents are widely distributed (broadcast) to many unconscious specialized networks; (iii) conversely a global workspace can also serve to integrate many competing and cooperating input networks; (iv) that some unconscious networks called contexts shape conscious contents; (v) that such contexts work together jointly to constrain conscious events; (vi) that motives and
emotions can be viewed as goal contexts; (vii) that executive functions work as hierarchies of goal contexts.

Working memory is an important factor in understanding individual differences in mathematical achievement in children. Research, on the role of working memory in mathematics performance, draws mainly on studies of children with mathematical disabilities indicating that deficits in mathematics are linked to poor working memory (Geary, Hamson, & Hoard, 2000; Passolunghi & Siegel, 2004). A majority of these correlational studies in typically or atypically developing children are cross-sectional.

Each component of working memory is thought to have specific role in mathematics performance (e.g., De Stefano & Lefevre, 2004). Evidence from dual-task studies has consistently shown the involvement of the central executive in arithmetic, indicating that this component is responsible for the monitoring and coordination of different steps during arithmetic problem solving (Imbo, Vandierendonck, & DeRammelaere, 2007). Turning to slave systems, it has been shown that the phonological loop plays an important role in arithmetic, presumably in counting or in keeping track of the operands while calculating (Noel, Seron, & Trovarelli, 2004). Turning to slave systems, it has been shown that the phonological loop plays an important role in arithmetic, presumably in counting or in keeping track of the operands while calculating (Furst & Hitch, 2000). Studies on visuospatial sketchpad are much less common but this component appears to be involved in subtraction, where number are assumed to be processed in magnitude code akin to a mental number line and in multi-digit calculation, where visuospatial sketchpad might be responsible for spatial aspects of calculation such as number alignment and carrying (Trbovich & Lefevre, 2003). Early levels of mathematics are one of the most powerful sources of individual differences in later mathematics.

More recent research has focused on the specific role of working memory in mathematical cognition. Several authors have found that
working memory plays a crucial role in calculation and in solving arithmetic word problems (Bull & Scerif, 2001; Geary, Hamson, & Hoard, 2000). Moreover, working memory has been implicated as a central deficit in children with mathematical disabilities (Passolunghi & Siegel, 2001). It has been found that children with specific difficulties in mathematics were impaired in working memory tasks that involve the processing of numerical information but not in other complex verbal span tasks. Similarly, Passolunghi and Siegel (2001) observed that children with a mathematical disability have a general working memory deficit and performed poorly on both numerical and verbal working memory tasks. Some researchers also found that children with specific mathematical difficulties had a persistent deficit in working memory that is not restricted to a numerical working memory task. Indeed, in complex working memory span tasks, children with difficulties in mathematics showed an impairment and lower recall of relevant information in all working memory tasks involving verbal or numerical information. However, in simple working memory span tasks children with mathematical disability showed a weakness particularly in the digit span backward task, which requires an active processing of numerical information but not impairment information.

**PASS Cognitive Processes**

Das and his colleagues (Das et al., 1975; Das, Naglieri, & Kirby, 1994) have offered the Planning, Attention, Simultaneous and Successive processing (PASS) theory as an alternative to the conceptualization of intelligence as a general mental ability. The popular approach to theory of human intelligence that considers human intellectual functioning as a single unitary quality underlying all cognitive processes (g) provides ideology for PASS theory of Intelligence. It challenges g-theory on the grounds that neuropsychological research has consistently demonstrated that the brain is made up of interdependent, but separate functional systems. Specifically, the PASS theory is based on the view that intelligence is composed of multiple inter-dependent cognitive processes.
The PASS theory has evolved through many years of theoretical and empirical work. Initially proposed and described as an information processing model derived from Luria (Das, 1973; Das, Kirby, & Jarman, 1975) and then as information-integration model (Das, Kirby, & Jarman, 1979), later the model was called the PASS model (Naglieri & Das, 1988, 1990). Further it was elaborated by Das, Naglieri and Kirby (1994); and Das, Kar and Parrila (1996) and referred to as PASS theory of intelligence. Das et al. (1994) believed that it has a strong theoretical foundation, has been sufficiently operationalized and is making significant contributions to the understanding of exceptionality and predict academic as well as job performance.

This view of intelligence is based on a neuropsychological work of Luria (1966, 1973) as well as cognitive psychological findings (Hunt & Lansman, 1986). According to Luria, human cognitive processing involves three functional systems that work in concert and whose participation is necessary for any type of mental activity (1973, p.43). The first functional unit is responsible for regulating cortical tone and maintenance of attention. The second unit receives, processes and stores information using simultaneous and successive information coding and the third unit programs, regulates and directs mental activity.

The first functional unit is associated with the brainstem, diencephalon and medial regions of the hemispheres. This is the base of human mental processes, because it maintains a proper state of arousal which allows for the focus of attention. The arousal aspect of the first functional unit is important because it provides the opportunity for the voluntary action of attention. Arousal is responsible for cortical tone and wakefulness and also attention which is more of a complex cognitive activity. Given an appropriate state of arousal, the two broad classes of selective and divided attention (Kahneman & Treisman, 1984) may occur. Any task involving the intentional discrimination between stimuli requires
selective attention, which is important activity of the first functional unit.

The second unit's functions are regulated by the occipital, parietal and temporal lobes posterior to the central sulcus. The cognitive functions of this unit are receiving, processing and retaining information which a person obtains from the external world. Luria (1966) stated that there is a strong evidence for distinguishing the two basic forms of integrative activity of the cerebral cortex, by which different aspects of the outside world may be reflected. These two types of processes are simultaneous processes which integration of stimuli into synchronous and primarily spatial groups and successive process which consists of integration of stimuli into temporally organized serial order.

The third functional unit described by Luria (1973) allows the individual to form plans of action, carry them out and verify the effectiveness of the plans. It relies on the second functional unit for processing components and the first functional unit for proper attentional status. With the prerequisite functioning of these units, the individual can develop plans of action, inspect performance and regulate behaviour so that it conforms to the plans and then compare the effects of these actions with the original intention so that correction of mistakes is possible. The third functional unit is also responsible for activities such as impulse control, regulation of voluntary actions and linguistic functions such as spontaneous speech (Luria, 1980, p. 517). Das (1984) and Arlin (1977) suggested that planning is the essence of human intelligence, as it involves the aptitude for asking new questions, solving problems and self-monitoring as well as the application of information coding processes.

Based on Luria’s seminal work on the modularization of brain function, and supported by decades of neuro-imaging research, the PASS theory divides intelligence into four interrelated cognitive processes as:
**Planning**- This is the ability to make decisions about how to solve problems and perform actions. It involves setting goals, anticipating consequences and using feedback. Planning also involves the attention-arousal, simultaneous and successive processing functions and is associated with the frontal lobes of the brain. Planning processes provide the individual with the facility to determine and utilize an efficient way to solve a problem through the application of attention, simultaneous and successive processes in conjunction with the base of knowledge. The three main aspects of planning are generation, selection, and execution. If more than one plan is found, selecting the best one is important and monitoring the effectiveness of these solutions is always needed.

**Attention-Arousal**- This involves the ability to selectively attend to stimuli while ignoring other distractions. Individuals with Attention Deficit Disorder (ADD) have impairments in this area. The arousal functions are generally associated with the brain stem and thalamus, whereas the higher attentional processes are thought to be related to the planning functions of the frontal lobe.

**Simultaneous Processing**- This involves the ability to integrate separate stimuli into a cohesive, interrelated whole. Simultaneous processing is necessary for language comprehension, as in: “Who is the person in the following statement: My mother’s father was his only son (Naglieri & Das, 1997)?” The occipital and parietal lobes are thought to be important for these functions. It also involves the integration of stimuli into groups or the recognition that a number of stimuli share a common characteristic. Both of these aspects require that all the stimuli be related to one another. Simultaneous processing may take place with perceived stimuli, remembered stimuli or the conceptual aspects of stimuli (Naglieri, 1985).

**Successive Processing**- This involves the ability to integrate stimuli into a sequential order. An example of this process is the sequencing of
letters and words in reading and writing. This type of processing is believed to be related to frontal-temporal lobe functioning (Das, 2002). The critical part of successive processing is that elements must be ordered without surveyability. In successive processing elements are only linearly related. Successive coding is needed for skilled movements because such activity requires a series of movements which follow each other in a strictly defined order without surveyability (Luria 1966, p. 78). In the early stages of the skilled movement each successive link exists as a separate unit and may be taught as a specific step in a larger behaviour. Only when each aspect becomes automatic can the initial stimulus in the chain become the signal that leads to the automatic execution of the complete successive action.

Figure: 3 PASS Theory Chart


According to the PASS theory, information first arrives at the senses from external and internal sources, at which point the four cognitive processes activate to analyze its meaning within the context of the individual’s knowledge base (e.g., semantic and episodic knowledge, implicit and procedural memories, and so on). Thus, the same information can be processed multiple ways (Das, 2002). Good planning typically involves a series of executive actions that includes various components. First, a task is presented to the individual and he is to determine how to solve the problem. Next, the need for a plan is determined and if a systematic approach to solving the problem is apparent individual searches his base of knowledge.
for an approach. Knowledge base is the context within which all cognitive processes operate. Information is received and processed and the output is programmed depending on knowledge base. This fund of accumulated knowledge can be thought of as the cumulative result of a person’s experiences that have been stored in memory. Because all processes operate within the context of knowledge, this base of information influences all cognitive processes and motor programs. Knowledge base includes information that has been accumulated through both formal and informal means. Formal knowledge is that which is acquired through instruction or reading and informal knowledge is that obtained by one’s experiences.

As far as the relationship among the PASS processes is concerned, it is viewed in light of the functional units as well as four cognitive processes. The three functional units are dynamic in that they respond to the experiences of the individual. They are subject to developmental changes and form an inter-related system. The functional units are all related while at the same time they maintain independence by having distinct functions. Knowledge base acts as a moderator for processing. Therefore, effective processing is accomplished through the integration of knowledge with planning, attention, simultaneous and successive processes as demanded by the particular task.

Because the PASS processes are interactive, they act in concert to provide specific functions to virtually all tasks performed in everyday life. However, all the processes are not equally involved in all the tasks. A close relationship has been described by Luria (1980), and Stuss, Benson et al. (1986) between planning and attention. It results from large number of neural connections between the first and third functional units in the brain. Planning requires an adequate state of arousal so that attention can be focused. An appropriate level of activation, attention and arousal is needed so that a plan of action can be generated and utilized. A similar strong correlation between coding and planning exists. Real life tasks can be coded
in different ways. How one manages the information is a planning function that influences the coding approach used (Lawson & Kirby, 1981; Kirby & Das 1978; Kirby & Lawson, 1983).

Planning processes are believed to be distinct from simultaneous, successive and attentional processes because they provide the individual the means to analyse cognitive activity, develop some method to solve a problem, evaluate the effectiveness of a solution, and modify the approach used as needed. These processes are necessary when an efficient and systematic approach to solving a problem is required.

The output component of the PASS processes is a complex function by itself. Simultaneous processes may predominate in the solution of a task, but motor programming may be required if the response is written one. An individual may have competence in processing, but fail to come up with the motor program required to respond. This can be a problem in special groups such as brain damaged and mentally handicapped individuals.

There are varied kind of evidences and studies that support PASS theory. PASS tasks are used to assess cognitive processes underlying intelligence, so importance of neuropsychological, factorial, achievement and diagnostic bases cannot be ignored (Das & Varnhagen, 1986; Leong, Cheng, & Das, 1985).

In order to establish the factorial validity of PASS, several studies have been conducted using Das-Naglieri Cognitive Assessment System (DN-CAS), a measurement instrument based on theoretical framework of PASS theory, published in 1997. Tasks intended to measure the third functional unit which relates to planning have been examined along with simultaneous and successive tasks for factorial validity. In this research, planning has emerged as a separate factor which is distinct from simultaneous and successive processing. Planning tasks ranged in complexity from the simple connection of numbers on a page (trail making) to more complex tasks such
as writing a story and playing a strategic game (Das & Heemsbergen, 1983). Results of factor analytic studies have found simple tasks such as Trail making and visual search to load with complex ones such as those involving written composition of a story (Ashman & Das, 1980), solving syllogistic reasoning items (Das & Heemsbergen, 1983), the Wisconsin card sorting task (Garofalo, 1986), and a pictorial category task (Schofield & Ashman, 1986). Two development tasks involving identification of two out of six identical numbers on a row (called matching numbers) and completion of a page of symbol/letter pairs (called planned codes) have also loaded with visual search and trail making studies by Naglieri and Das (1988) and Stutzman (1986). Das (1984), Das and Dash (1983) showed how speed of reading words and speed of saying the color of an object did not load with planning factors identified using the timed tasks visual search and trail making.

Whereas on attention, Naglieri, Das, Stevens and Ledbetter (1990) and Naglieri, Prewett and Bardos (1989) have found selective attention measures similar to those used by Posner and Boies (1971), and Stroop (1935) to be useful in assessment of attention.

Research by Das (e.g., Das 1972; Das, Kirby, & Jarman, 1975; 1979) has clearly shown that the simultaneous and successive information coding component of the PASS processes has construct validity. These researchers and others have found simultaneous and successive factors and evidence of developmental differences by chronological and mental age using tests such as progressive matrices, memory for designs and figure copying (simultaneous), and digit span forward, sound blending and sentence repetition (successive). The studies have involved samples of elementary and middle school-aged students (Das, 1972, 1973; Das & Molloy, 1975; Garofalo, 1986; Jarman & Das, 1977; Kirby & Das, 1978; Kirby & Robinson, 1987; Naglieri & Das, 1988), high-school aged samples (Naglieri & Das, 1988), and adults (Das & Heemsbergen, 1983; McCallum, & Merritt, 1983; Merritt & McCallum, 1983; Wachs & Harris, 1986; Ashman, 1982).
Validity for tasks used to measure the second functional unit has also been found with various types of exceptional children. Simultaneous and successive factors have been identified by several researches for samples of normal (Das & Dash, 1983; Das, Kirby & Jarman, 1975; Naglieri & Das, 1988), mentally retarded (Ashman, 1982; Cummins & Das, 1980; Das, 1972; Das, Cummins, Kirby & Jarman, 1979; Das & Molloy, 1975; Leong, 1980), learning disabled (Das, Leong, & Williams, 1978), and gifted (Karnes & McCallum, 1983; Snart, O'Grady & Das, 1982) children and adults.

The cross-cultural validity of PASS theory has been identified in a range of culturally distinct settings. Leong, Cheng, and Das (1985) found evidence for simultaneous and successive processing, as well as planning, in a sample of normal Chinese students in Hong Kong, and a significant relationship between reading and each of PASS processes, as did Naglieri and Das (1988). In other similar investigations Mwa mwenda, Dash and Das (1984); and Dash, Puhan and Mahapatra (1985) found support for simultaneous and successive processing factors with samples of children in India. Several investigations have reported simultaneous and successive factors in samples of Canadian (Das, 1973; Das, Bisanz, & Mancini, 1984), Canadian Native (Krywaniuk & Das, 1976), American (Naglieri & Das, 1988; Wachs & Harris, 1986), Australian (Schofield & Ashman 1986), and Australian Aboriginals (Klich & Davison, 1984) children.

Recently, many researches have been conducted with basic aim to test the culture specific efficiency of PASS theory on normal as well as special children. DN-CAS has been translated into Chinese, Greek, Dutch, Spanish and Japanese languages. In context of Chinese population, it was found that all the subtests of the CAS battery demonstrated acceptable reliability (Cai, Deng et al., 2013). Almost similar trend of results were obtained for Spanish, Dutch and Greek populations. In Japan, translation and comparison of obtained scores with U.S. population was done and it was found that standard scores of normal Japanese children were superior to
normal U.S. population (Das et al., 2013). In India, DN-CAS was used on low and high achieving children and scores were compared with Canadian population. It was found that low as well as high achieving Indian children scored high on Successive processing when compared with Canadian counterparts (Das et al., 2013). These studies provide evidence that tasks used to operationalize simultaneous, successive and planning processes have functional similarity despite wide differences in culture, language and socioeconomic status.

PASS is not just a theory of intelligence test performance, but of cognition in general. PASS provides a framework within which achievement skills may be understood and thus a firm basis for diagnosing and remediating children’s learning problems. The planning and attention components of PASS processes are particularly important for understanding achievement. It is very possible that achievement within a particular narrow domain is a function the interaction of planning, attention, simultaneous and successive processes with a particular knowledge base. Planning processes are most critical in those activities requiring the use of unique or non-routinized solution to problems. From a huge repertoire of information available, individual selects by attention relevance only, apply the appropriate processes, and determine how these three processes will be applied and maintained to bring the task to a successful completion.

PASS measures are empirically related to achievement measures. This has been done employing many different achievement measures along with CAS. Various aspects of reading achievement have been shown to be significantly related to simultaneous and successive processes (Cummins & Das, 1978; Kirby & Das, 1977, Naglieri & Das, 1987) and to planning (Das, 1984). Measures of mathematics achievement have been shown to be related to simultaneous and successive processing (Garofalo, 1986; Naglieri & Das, 1987), to planning (Ashman & Das, 1980; Das & Heemsbergen, 1983; Garofalo, 1986; Kirby & Ashman, 1984), and to attention (Warrick, 1989).
One unusual property of the PASS theory of Intelligence is that it has proven useful for both intellectual assessment (e.g., the CAS) and educational intervention (PREP). One aim of diagnosis is to determine if there exists congruence between an individual’s cognitive processing competence and academic or job requirements. Due to relatively greater complexity of the PASS theory and the increased perspective with which it views cognitive processes, there is an increased potential for sensitivity to personal variations. Through the changed perspective from which intelligence is viewed, more efficient diagnostic power for exceptional children such as learning disabled is possible. This has been supported by Bardos (1988) who found that through the addition of planning and attention measures, identification of individuals as learning disabled and mentally retarded was improved over the use of information coding (simultaneous and successive processing) measures alone. This finding is consistent with those of Naglieri (1985) and Naglieri and Haddad (1984) in which measurement of simultaneous and successive processing alone were not considered sufficient to diagnose a learning disability. Over the span of last 20 years, a wide variety of research has been conducted on different kind of samples like learning disabled (RD, MLD etc), dyslexic, ADHD children, hearing impaired, and children with traumatic brain injury. Results have clearly indicated the sensitivity of PASS theory to cognitive deficits in special children.

Numerous studies have been carried out in the last few decades, to examine the role PASS processes in academic achievement among normal as well as children with special needs. Results of the studies investigating unique contribution of PASS processes in mathematical achievement present more or less mixed views (Abougoush, 2014). Though joint variance accounted for by PASS processes may vary in studies (Kroesbergen et al., 2003; Georgiou et al., in press) yet planning and simultaneous processing have been shown to be significant predictors in mathematics time and again.
(Cai et al., 2013; Naglieri & Rojahn, 2004). These PASS cognitive processes have also been observed to have influence on word reading and reading achievement (Das et al., 2008; Wang et al, 2012).

**PASS and other Cognitive Theories of Intelligence**

Contemporary theories about intelligence can be divided into two classes, psychometric and cognitive. Some of the main followers of the alternative approach of cognitive intelligence have been Jensen (1970, 1980) and Das et al. (1975, 1977). Jensen (1968, 1970) postulated the notion of two-level theory of mental abilities to account for the differences in cognitive test performance of certain racial and social class groups. Level I ability is described as an associative ability in which the correspondence between stimulus information response output is relatively simple and direct. In contrast, Level II ability is described as conceptual ability in which the original stimulus information for learning is transformed and elaborated before the response can be made. Level I and Level II can be taken as two poles of continuum along which tasks can be arranged in terms of degree of complexity of cognitive demands.

Das's PASS model observed that a number of inconsistencies in Level I/II data could be interpreted with knowledge of types of transformation (e.g., simultaneous and successive) rather than amount of information transformation (Level I and II). Jarman (1978) took some issues and stated that the evidence indicating that memory tasks are performed using various strategies raised question regarding validity of labeling Level I position to different memory tasks. Another line of evidence dealt with role of control processes in memory i.e. different subjects or groups may perform same tasks via different abilities. Then a test might stand at different points on Level I and Level II continuum in a population than in another population. Further the distinction between Level I and Level II appeared to be an assumption that was dysfunctional in attempt to consider memory as distinct from other cognitive processes. The difficulty in level I/II theory did
not confine only to Level I ability. Rather definition of Level II seemed open to debate.

However, similar inconsistencies were also found in data used in Das’s model. The inconsistencies though, were largely explained as between-subjects and possibly between-groups differences in preference for one or the other mode of processing, it was believed to be representing the basic difference between Das’s and Jensen’s theory. Whereas Level I and Level II represent abilities that are determined, to large extent, by the tasks used to measure them, the use of simultaneous and successive processing could be a function of individuals’ cognitive style i.e. to synthesize stimulus in a particular manner.

Majority of researches supporting Cattell’s notion of fluid and crystallized intelligence found that Jensen’s Level II is not a unitary concept. Factorially, it divides into two broad factors. Evidence indicated that Level I relates to memory and Level II to gf-gc (Darolia, 1985; Jensen & Reynolds, 1982; Townsend, 1982). Similarly, Das’s simultaneous synthesis was believed to be tapped by gf-gc both. Therefore Cattell’s gf and gc component represent Level II or Das’s simultaneous synthesis.

Cattell-Horn-Carroll theory or CHC theory of cognitive abilities is considered to be the most comprehensive and empirically supported psychometric theory of structure of cognitive and academic abilities (McGrew, 2005). It is an amalgamation of two theories, first being gf - gc theory (Cattell, 1943; Horn, 1965) and second being Three-stratum theory of Carroll (1993). The CHC model was later expanded and revised by McGrew and Flanagan (1998). Further it was extended by Schneider and McGrew (2012). This theory holds that relationship among different types of cognitive abilities can be derived by classifying them into 3 different strata: Stratum I (narrow abilities), Stratum II (broad abilities), and Stratum III consisting of single general ability. CHC theory includes 9 broad cognitive abilities subsumed over by 70 narrow abilities. The broad abilities include
crystallised intelligence (Gc), fluid intelligence (Gf), quantitative reasoning (Gq), reading and writing ability (Grw), short-term memory (Gsm), long-term storage and retrieval (Glr), visual processing (Gv), auditory processing (Ga), and processing speed (Gs). Later, Schneider and McGrew (2012) extended to 18 broad abilities and over 80 narrow abilities.

While addressing some important and unresolved issues concerning validity of PASS theory and CAS (measure based on PASS), Kranzler and Keith (1999) analysed the standardized data using confirmatory factor analysis and found that results did not support construct validity of CAS. Although the Das and colleagues provided evidence in the manual and elsewhere that the CAS in fact measured PASS abilities (Naglieri, 1999, 2005), other researchers provided evidence that the test instead measured constructs that were quite consistent with CHC theory, and not PASS (Carroll, 1995; Keith & Kranzler, 1999; Kranzler & Keith, 1999; Kranzler, Keith, & Flanagan, 2000; Kranzler & Weng, 1995). The research suggested that the constructs measured by CAS could be best understood within CHC theory as processing speed (instead of Planning and Attention), memory span (rather than Successive Processing) and a mixture of fluid intelligence and broad visualization (instead of Simultaneous Processing). It was also concluded that the theoretical model underlying CAS did not provide best description of its factor structure, most of PASS scales have had insufficient unique variance to be interpreted in isolation and the structure of CAS is better explained from an alternative theoretical perspective (i.e. CHC). Later Kranzler, Keith and Reynolds (2000) examined the factor structure of CAS independently. They also examined hierarchical models. The first model was based the actual structure of CAS, whereas the second model was PASS + g. It had g at the apex (reflecting FS of CAS), and four first order factors corresponding to PASS scaled scores (Keith & Kranzler, 1999; Kranzler & Keith, 1999; Naglieri, 1999). This hierarchical PASS model fit the data as well as the PASS model and was found to be more parsimonious explanation of CAS factor structure. In another study, Keith et al. (2001) compared CAS with Woodcock Johnson test-III and found results similar to Keith and
Kranzler (1999). Lastly, this research also supported the third stratum of CHC theory. Although PASS theory and the CAS deny a g-type factor, the higher-order g factor from the CAS in fact correlated .98 with the WJ-III g factor, and the two were statistically indistinguishable (Keith et al., 2001).

Though PASS theory and CHC theory initially started as rivals, but some thoughtful scholars have begun to show that they can be integrated productively (Flanagan, Alfonso & Dixon, 2014; Kaufman & Kaufman, 2004). Schneider (2014) pointed out that if observation data were used to develop a robust model of the relationship between strategy use of CAS and Processing Speed ability, then procedures could be developed such that these measures would become even more sensitive to the needs of the children and hence could contribute efficiently for diagnosis of deficits among children and adolescents.

Despite the fact that the different cognitive theorists consider themselves as being the alternative approach to intelligence, it has been observed that they relate with each other as well as with the commonly accepted notion of intelligence (g). In such a perplexing situation it becomes relevant to test these alternative theories to explain individual differences in a variety of sample population so that it can be understood whether such theories are sensitive to the demands and needs of that particular sample or not. The present study is an attempt to use PASS theory of Intelligence to explain deficits and concerns relating to children with low mathematical abilities or difficulties.

**Rationale for the study**

It is a point of common observation that mathematical ability is an important everyday skill that is a key component of elementary education. There is an established literature in the area that has examined the arithmetic and counting in both normal and learning disabled adults and children (e.g., Logie et al., 1994). 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., 2010). 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 recent 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 recently 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. Therefore, more studies with cognitive processes of this kind are required.

Therefore, the proposed investigation focuses on the study of low mathematical ability children and their underlying cognitive skills; therefore, a test based on a theory like the PASS seems 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 problem of the present study may be 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.