Working Memory and Mathematical Performance: A Correlational Study

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Abstract *This study is intended to examine the correlation between working memory of students and their academic performance in Mathematics. Specifically, it was aimed to determine the degree of relationship between working memory capacity and academic achievement of students in mathematics studying at secondary school. A sample of 800 students studying in grade 10 was randomly selected from forty government and private secondary schools (girls and boys) situated in Hazara division, Khyber Pakhtunkhwa, Pakistan. Both Urdu and English mediums of instruction schools were included in the sample. The researcher used digits span backwards test (DSBT) to find out the working memory capacity of the students associated with their academic performance in mathematics. This study revealed that girls have outperformed boys very markedly in examination scores of mathematics at secondary level. Contrarily, boys have performed well in working memory capacity than girls at the secondary level. However a very small gender difference is observed in this study. It is also noticed that private secondary schools showed higher performance in examination scores of mathematics and in working memory capacity than government secondary schoolsl.*

Key Words:

Working Memory, Academic Achievement, Relationship, Mathematical Thinking, Secondary Schools

Introduction

Mathematics has an active role to play in every area of human life so education of it cannot be ignored. Mathematics has an important place in the curriculum and it is a compulsory subject in almost all of over the world (Al-Enezi, 2008). Mathematics can be detached from the life of man as it provides a social base in fulfilling his needs.

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All students in formal schools, study mathematics up to grade 10 in Pakistan. This is only a subject in which all students are forced to think to enable them to pursue their further education and to solve their daily life problems. It also provides a necessary base for other subjects. The study of mathematics is a requirement of all sciences, technological fields, engineering, bio-medical studies, and economics. All professionals also used mathematical work, for example, engineers, account officers, and the commercial world.

The mathematics related ideas are extremely abstract. Even simple calculations like subtraction and division are abstract while others are more abstract. Teaching of mathematics is used to sharpen the abstract thinking of the learners for the development of their learners' minds. The mathematics gives a description of the universe in the form of measurement which is required to describe the position of space and time is proved by Einstein in the form of whole areas of quantum theory and chemical bonding mathematically. Learning of mathematics is considered difficult.

There are many research studies in which it is evident that individual to individual variation in working memory capacity are foretelling of cognitive abilities of persons when they perform different complex activities and function. (Fukuda, Vogel, Mayr, & Awh, 2010; Johnson, et al, 2013).

First part of the memory is sensory where information is received. In this part of the memory perceptions are filtered (Johnstone, 1997). Then this information passed through the senses and entered into short term memory because one can retain very little information in sensory memory (Gross, 2005).
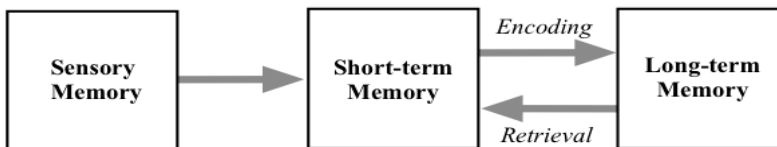

Figure 1: Memory Model

There is a vital role of working memory in all sphere of learning processes. The working memory was once known as 'short-term memory' and Miller (1956) proved ways that it can be measured.
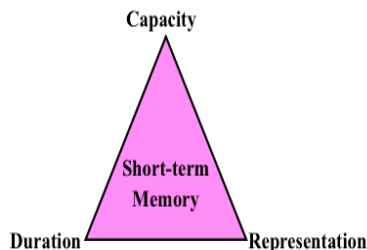
Figure 2: Short Term Memory

Later on Baddeley (1986, 1997, 1999, 2000) worked on working memory. In science education, others also worked in this field (Johnstone & Kellett, 1980; Johnstone & El-Banna, 1989; Johnstone, 1991, 1997).
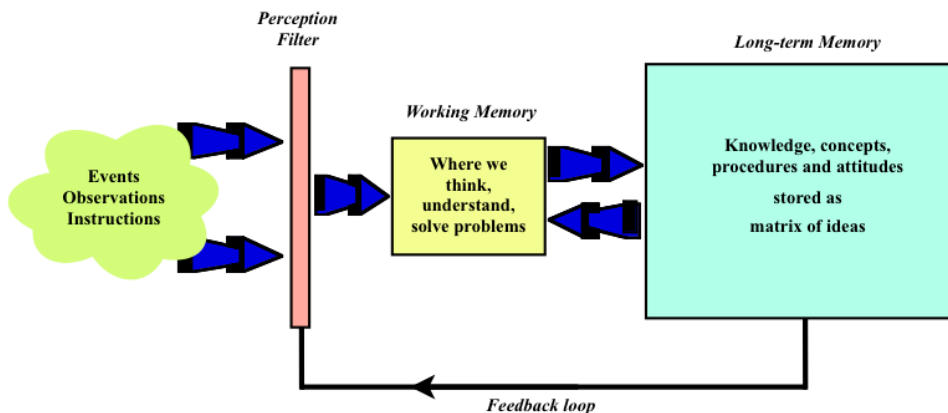

Figure 3: Learning Process

The working memory capacity is regarded as a psychological and physical space as information coming in mind for short time, where interaction of new information with long-term memory took place, and can be operated. In learning context, it is a space where the thinking and comprehension process in the mind of learner started to makes the sense of information to use in problem solving. The information processed in working memory has been brought to store in the long-term memory to leave space for new work (Johnstone, 1997).

The academic achievement of the students related to socially developed objectives based on levels and capacity of learners in terms of knowledge, disposition and skills. At the time of writing the age and prior learning of the students are considered for their education. Johnstone and Selepeng (2001) stated that little understanding of language puts a load on inadequate working memory means and study of Durkin and Shire (1991) stated the particular difficulties language makes in mathematics with young kids and how this has direct relationship with the attainment. The capacity of working memory is spent to resolve language problems and disturbs the mathematical thinking (Johnstone & Selepeng, 2001).

The overall relationship has been established between academic achievement in mathematics and the working memory of the students by many (Christou, 2001). Johnstone and El-Banna (1989) described that student's low working memory is resulted their low performance.

Al-Ahmadi and Reid (2011) have given the operational definition of the scientific thinking whereas Al-Osaimi, Reid, and Rodrigues (2014) developed a model for critical thinking. Earlier, Chandi (2008) had given an operational systems for thinking. Considering the distinctive mathematical thinking that makes it different from additional ranges of thinking. The main result of this study is relationship among variables, constant, space etc.). Working memory is considered as an essential factor in learning (Reid, 2009a, 2009b). This has been proven that achievement in test is strongly related to capacity of working memory. Johnstone and El-Banna (1989) revealed about the relationship is the cause and effect. This has been described in the following model (figure 1).
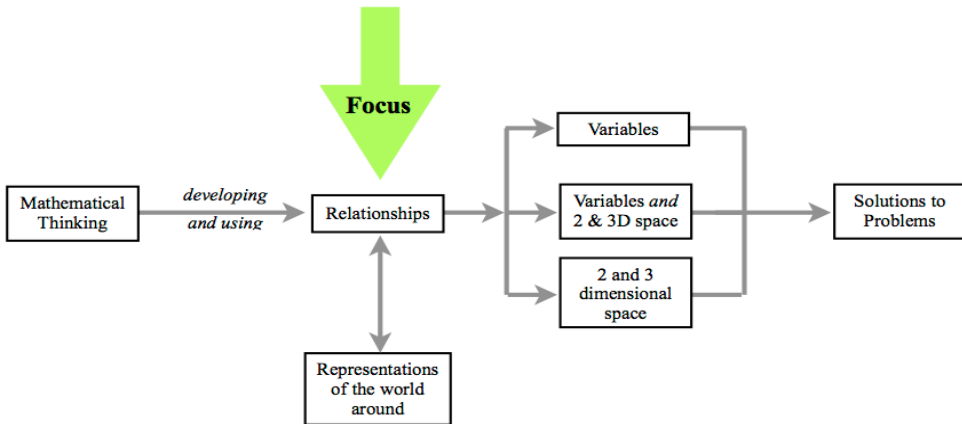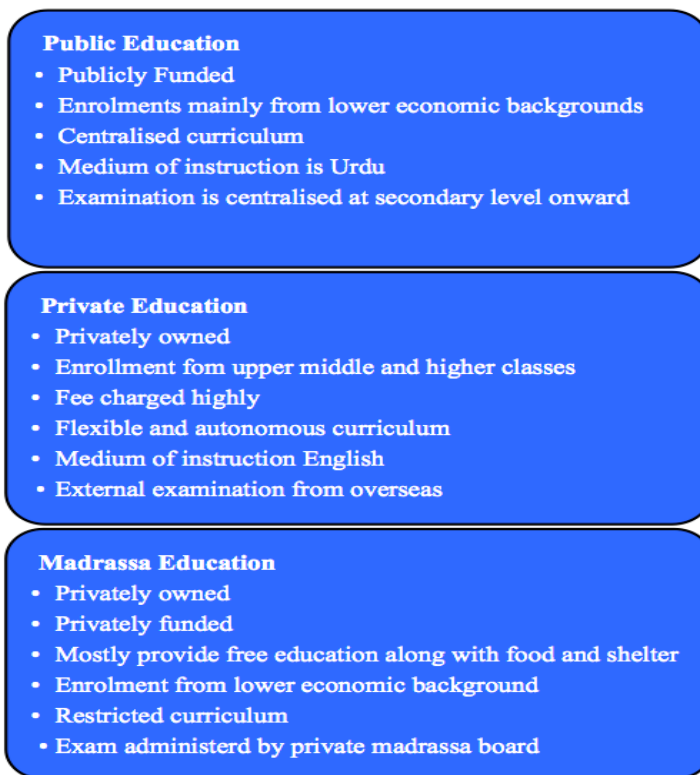

Figure 4: Thinking for Mathematics

In Pakistan, Ministry of Education is responsible for education. In Pakistan like many developing countries, the administrative structure of education is described with a "pyramid model". The administrative set up for education at national, provincial, district and local levels is given as under:
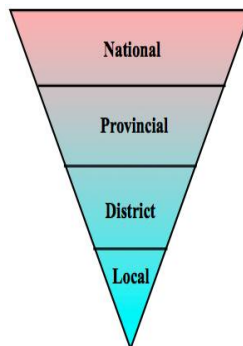
Figure 5: The Pyramid Model

There are three types in the educational system in Pakistan: public educational institutes, private educational institutes and religious educational institutes (Madrassas). They are given as under in figure 6:

Public Education
- **Publicly Funded**
- **Enrolments mainly from lower economic backgrounds**
- **Centralised curriculum**
- **Medium of instruction is Urdu**
- **Examination is centralised at secondary level onward**

Private Education
- **Privately owned**
- **Enrollment fom upper middle and higher classes**
- **Fee charged highly**
- **Flexible and autonomous curriculum**
- **Medium of instruction English**
- **External examination from overseas**

Madrassa Education
- **Privately owned**
- **Privately funded**
- **Mostly provide free education along with food and shelter**
- **Enrolment from lower economic background**
- **Restricted curriculum**
- **Exam administerd by private madrassa board**

Figure 6: Three Streams in Pakistan

There are three main streams which are quite different with each other in the form of curriculum, teaching strategies, fees, enrolment and ownership. The educational system in Pakistan can be summarized as in figure 6.

The Boards of Intermediate and Secondary Education (BISE) conduct examination of Secondary School Certificate (SSC) students enrolled in government and private schools. A-level examinations are conducted by Cambridge or London university external examination at A or O levels and develop their own exams or assessment procedure for higher education.

The main purpose of this undergone research study was to investigate the relationship between working memory of the students and their academic achievement in mathematics.

Objective of the Study

The research objective was to determine the degree of relationship between working memory capacity of the students and academic achievement of students in mathematics studying at secondary school.

Research Methodology

Non experimental quantitative approach was used to determine the degree of relationship between working memory of the students and their academic achievement of students in terms of BISE results grade 9 in subject mathematics. The working memory capacity and the academic achievement of students in mathematics were two key variables of this study. The research instrument, data collection and analysis procedures were discussed in this sections.

Sample

A sample of 800 students studying in grade 10 was randomly selected from forty government and private secondary schools (girls and boys). Both Urdu and English mediums of instruction schools were included in sample.

Research Instrument Used

The researcher used digits span backwards test (DSBT) to find out the working memory capacity of the students associated with their in mathematical performance. The researcher started to read some digits in an order before the students and asked them to write the digits in backward order. For example, '3 9 1 4 2' would return as '2 4 1 9 3'. The reading speed for a digit per second is required for different levels. When students finish one level they were asked a new number having more digits in number and so on. For each number, there were two tasks. After making mistakes by the student for a particular level is considered as working memory has gotten its capacity.

To make the students familiar before DSBT, a digits span test is used just to measure recall capacity. The DSBT has been used for many years requiring extreme care. The time of reading per second the digits must be noted so that students should not be able to cheat by backwards writing numbers.

The researcher used technique of Danili (2001) originally developed by Johnstone. The sample was distributed in three groups. The groups were defined as follows: above average (working memory ≥ 7), average (working memory $= 6$), and below average (working memory ≤ 5).

Table 1. Working Memory Test Scores

N=800	Working Memory Capacity					
WMC Test Scores	5 or Less Below Average		6		7 or More	
			Average		Above Average	
Number of Students (%)	N= 288	36%	N= 272	34%	N= 240	30%

Table 1 indicated that 288 (36%) students have (WMC≤ 5) (below average), 272 (34%) students have working memory capacity (WMC=5) (average) and 240 (30%) students (WMC≥ 7) (above average).

Reliability and Validity of the Test

The reliability and validity (consistency 92%) of DSBT was established by El-Banna (1987, page 62) to measure working memory. DSBT provides real results in the form of original ability of the students but less than one in space when the digits of the numbered are reversed.

Mathematics Achievement

The mathematics achievement of the 800 grade 10 students were taken from BISE Abbottabad examination marks obtained in mathematics held in 2011 (when these students were in grade 9) for finding correlation between marks and working memory capacity of the students. The students secured marks out of 75 these marks are taken as academic achievement of student in mathematics.

Table 2. Marks Distribution of Students

N=800	Mathematics Scores			(BISE Exam 2011)		
Test Range	25		25-50		51-75	
Categories	Low Achievers		Average		High Achievers	
Average Score Gained (%)	N= 40	5%	N=329	41%	N= 431	54%

Table 2 reveal that 40 (5%) students secured 25 marks (low achievers), 329 (41%) students' secured 25-50 marks (average achievers) and 431 (54%) students secured 51-75 marks (high achievers).
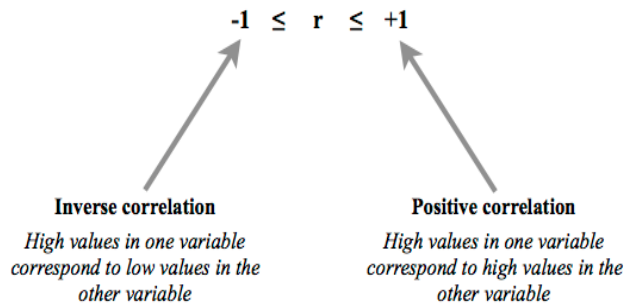
Data Collection

The researcher approached the school heads after getting permission to conduct study and one teacher from each school to facilitate in data collection. The

researcher with the help of school teacher applied the DSBT and asked the participant grade 10 student to write the marks of mathematics obtained in BISE grade 9 examination. The marks written by the students were verified by school administration. The participants keenly took interest during test activity. The heads and teachers for giving full cooperation for all data collection process.

Analysis and Interpretation of Data

The collected data were analyzed using frequency distribution and found having normal distribution because collect data were continuous. For calculation of the relationship between both continuous data normally suggested to use Pearson correlation. The researchers also used Pearson correlation to calculate the correlation among working memory and students' achievement scores

A random sample of (N=800) secondary level students including girls (n=400) and boys (n=400) was acquired. Overall 800 students were selected from 40 secondary schools' level. From each school 20 students were chosen. The sample was collected from both the private and Government schools. Respondents were students of only grade 10 of arts and sciences.

$$-1 \leq r \leq +1$$

**Inverse correlation**
High values in one variable correspond to low values in the other variable

Positive correlation
High values in one variable correspond to high values in the other variable

Figure 7:   Correlation

Overall Data

Table 3. Descriptive Data

N = 800	Min	Max	M	SD
Examination	21	75	52	15.4
Working Memory Capacity	2	9	5.8	1.27

The examination marks in the subject of mathematics show a good spread. Mean 52 with SD 15.4 for mathematics achievement scores and Mean 5.8 with SD 1.27 for working memory capacity.
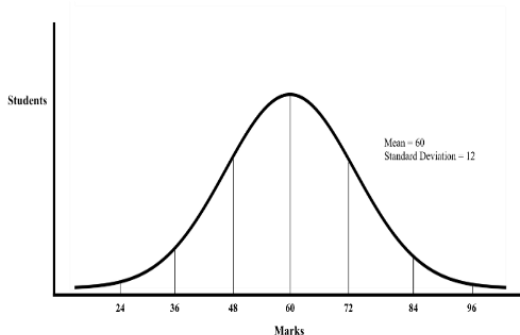
Figure 8:'Ideal' Examination Mark Distribution

The analysis of the sub-groups is given descriptively in table 4.

Table 4. Descriptive Analysis for Type of School and Gender

	Boys Private Schools		Girls Private Schools		Boys Government Schools		Girls Government Schools	
	N = 200		N = 200		N = 200		N = 200	
	M	SD	M	SD	M	SD	M	SD
Examination	63	9.1	66	5.8	37	9.2	41	10.1
Working Memory Capacity	6.3	1.1	6.1	1.1	5.5	1.3	5.4	1.3

Table 4 shows that mean examination scores in the subject of mathematics of boys' private student is (M = 63) remarkedly higher than mean (M = 37) of boys' government students. Similarly mean working memory capacity scores in the subject of mathematics of boys' private student are (M = 6.3) higher than mean (M = 5.5) of boys' government students.

Likewise, table 4 also depict that mean examination scores in the subject of mathematics of girls' private student is (M = 66) prominently higher than mean (M = 41) of girls' government students. Similarly mean working memory capacity scores in the subject of mathematics of girls' private student are (M = 6.1) higher than mean (M = 5.4) of girls' government students. It illustrates that private schools outperform in examination and in working memory capacity. It also appears that girls showed higher performance than boys in examinations in both type of schools.

Table 5. Mean Difference between Boys and Girls on Variable of Examination (N = 800)

Variable	Girls (n = 400)		Boys (n=400)		t (798)	p	95% CI		Cohen's d
	M	SD	M	SD			LL	UL	
Examination	54	14.9	50	15.7	3.5	<0.001	-1.20	1.80	0.26

Table 5 shows statistically significant difference between girls and boys scores on examination. Table 5 also revealed Mean value of girls (M = 54) is markedly greater than boys (M = 50). Cohen's d value also reveals the small effect size of gender on examination results.

Table 6. Mean Difference between Boys and Girls on Variable of Working Memory (N = 800)

Variable	Girls (n = 400)		Boys (n=400)		t (798)	p	95% CI		Cohen's d
	M	SD	M	SD			LL	UL	
Working Memory	5.7	1.3	5.9	1.3	2.1	<.05	-0.03	0.79	-0.15

Table 6 shows statistically significant difference between girls and boys scores on working memory. Table also revealed Mean value of boys (M = 5.9) is slightly greater than girls (M = 5.7). Cohen's d value also reveals the small effect size of gender on working memory.

Table 7. Mean Difference between Government School Students and Private School Students on Variable of Examination and Working Memory (N = 800)

Measures	Government School (n=400)		Private School (n=400)		t (261)	p	95% CI		Cohen's d
	M	SD	M	SD			LL	UL	
Examination	65	7.9	40	9.9	39.8	<.001	2.13	3.88	2.91
Working Memory	5.5	1.3	6.2	1.1	8.7	<.01	-0.71	-0.47	-0.58

Table 7 exhibited statistically significant difference between government school and private school on examination scores of the students on subject of

Mathematics. Table also revealed Mean value of government school (M = 65) is distinctly greater than private school (M = 40). Cohen's d value also reveals the large effect size of sector on examination results. Table 7 depicts statistically significant difference between government school and private school on working memory of the students studying Mathematics at secondary level. Table also revealed Mean value of working memory of private school (M = 6.2) is slightly greater than government school (M = 5.5). Cohen's d value also reveals the small effect size on working memory.

Academic achievement

The scores distribution is shown in figure 9.

Total Sample N = 800
Mean = 52
Standard deviation = 15.4
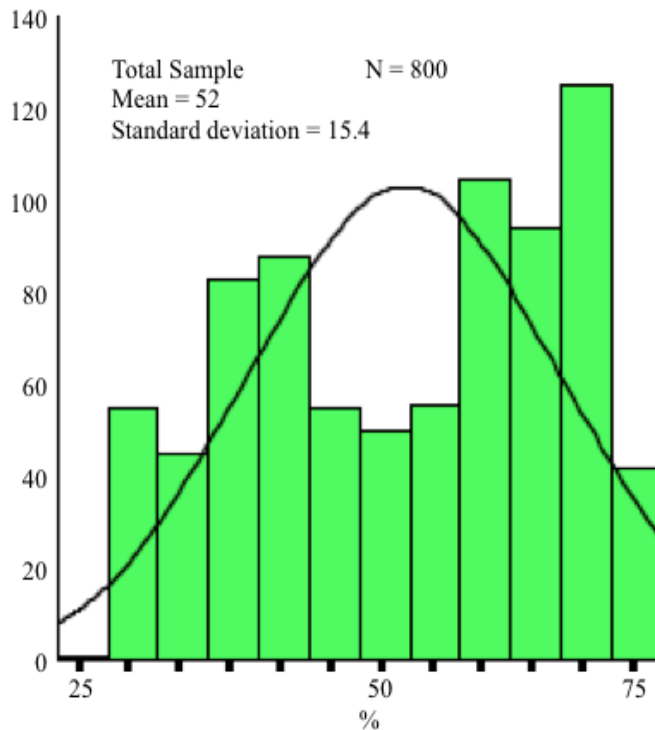
Figure 9:   Performance in Examinations (total sample)

Figure 9 demonstrates a bimodal arrangement of a whole sample comprised of two samples. This histogram revealed Mean value is 52 and SD is 15.4.

The distribution of performance in examination is close enough to normal of use Pearson correlation (figure 10).
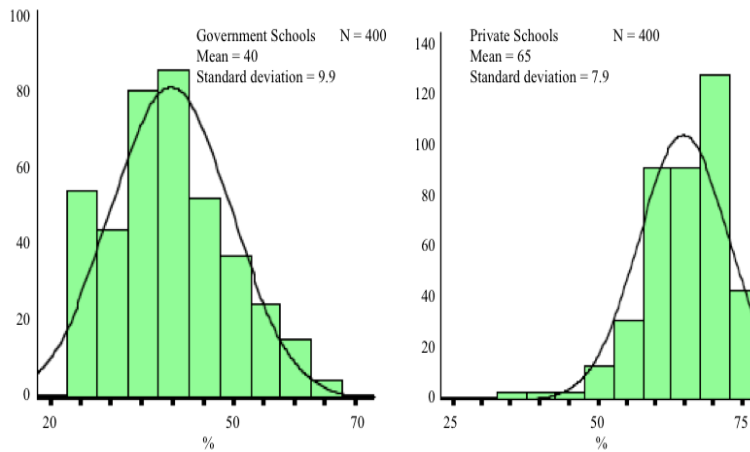
Figure 10:   Performance in Examinations (by School Type)

The figure 10 illustrates the difference in performance between the two types of school (government and private). Curve showing Mean value of private school (M=65) is clearly greater than government school (M=40). Perhaps, the private sector schools are attracting much more able learners and this is reflected in their academic achievement in the form of BISE grade 9 results in mathematics.
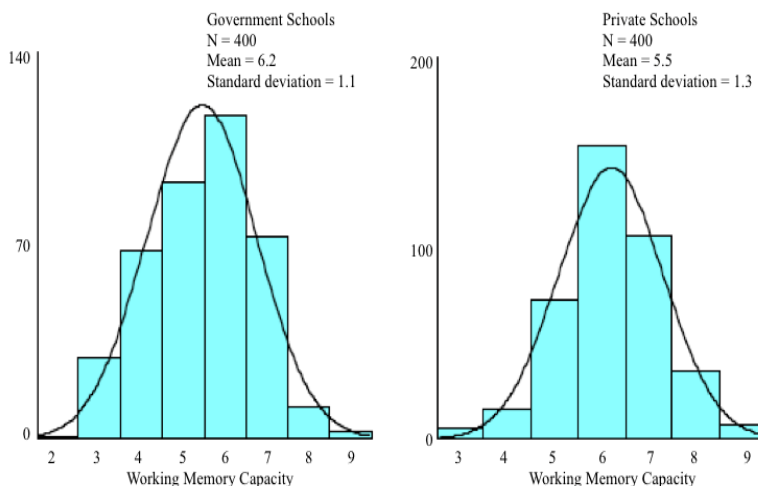
Working Memory

The distribution of working memory capacity is given in following figure 11.
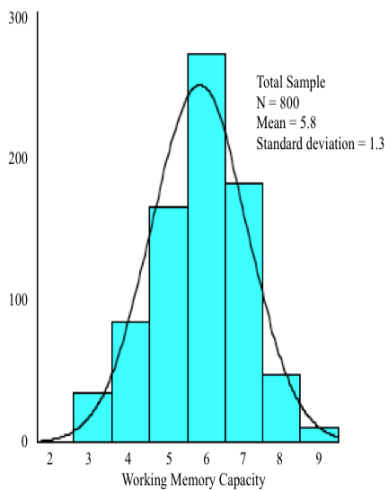
Figure 11:   Working Memory Capacity of Whole Sample

Figure 11 is showing almost perfect normal distribution. The mean score (M=5.8) for working memory capacity of whole sample is approximately expected for grade 10 students.

The distributions for the both government and private schools show variations (Figure 12).

Figure 12:   Working Memory Capacity (by School Type)

Figure 12 exposed mean value (M=6.2) for working memory of private school students which is slightly greater than mean value (M=5.5) of government school students, which shows marked difference between two types of school.

Table 9. The Effect of Working Memory of Students on their Academic Achievement

N = 800	Working Memory Capacity		
	Above average (N = 240)	Average (N = 272)	Below average (N = 288)
Average Marks Secured (%)	58.8	54.4	44.2
Correlation Ratio	r =0.43 (p < 0.001)		

Table 9 shows that there are three groups on the basis are working memory capacity above average (WMC ≥7, N=240), average (WMC =6, N=272) and below average (WMC ≤ 6, N=288) having average marks (%) gained 58.8%, 54.4% and 44.2%. respectively. This implies the difference of average mark gained (%) among number of students on the basis of working memory capacity given in

above groups are not high (only 14.6% above average and average). The correlation ratio (r=0.43, p < 0.001) between the working memory capacity and marks gained in mathematics is highly significant.

Results and Discussion

Although several studies always indicated that the relationship between working memory capacity and academic achievement is statistically significant. This type of relationship is for a very few studies. Johnstone and El-Banna (1989) indicated as is cause-and-effect. Ali and Reid (2012) stated "working memory capacity can only correlate with performance if teaching and learning process is such that students with higher working memory capacities have an advantage and the assessment is such that students with higher working memory capacities have an advantage".

There is a significant difference between girls and boys scores on examination. The Mean value of girls (M = 54) is markedly greater than boys (M = 50). It shows that girls performed better than boys in examinations in both government and private schools. Hence, results exposed clearly that girls performed better than boys. Ali and Reid (2012) found normally no gender differences at the time of measuring working memory. Although, quite little differences in gender is found in this study.

Results revealed statistically significant difference between girls and boys scores on working memory. Table also revealed Mean value of boys (M = 5.9) is slightly greater than girls (M = 5.7). Mean value of private school (M = 65) is distinctly greater than government school (M = 40). The difference in academic achievement between the two types of schools was considerable. Obviously, students of better ability are attracted by the private schools which is revealed in the examination performance.

There is a significant difference between government school and private school on working memory of the students studying Mathematics at secondary level. Table also revealed Mean value of working memory of private school (M = 6.2) is slightly greater than government school (M = 5.5). Chu and Reid (2012) discovered correlation ratio (0.62) with 38% variation in working memory) wheras in Pakistan, Ali and Reid (2012) found correlation 0.69 in mathematics (48% variance)

Conclusion

This study revealed that girls have outperformed boys very markedly in examination scores of mathematics at secondary level. The current study also found that girls may have had the potential to perform better than boys in mathematics this is may be caused by developmental reasons such as girls are very

mature at this stage than boys. However, boys' performance may have been attenuated as they rely mostly on recalling pervious knowledge low willingness to respond to assessment.

The Contrariwise, boys have performed well in working memory capacity than girls at the secondary level. There are normally no gender differences are found in literature. However the very small gender difference is observed here. It is also noticed that private secondary schools showed higher performance in examination scores of mathematics and in working memory capacity than government secondary schools level.

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