Bulletin of Education and Research
December 2019, Vol. 41, No. 3 pp. 177-192

The Relationship between Students' Working Memory Capacity and Mathematical Performance at Secondary School Level

Tahira Batool*, Umm e Habiba** and Amna Saeed ***

Abstract

The aim of this study is to investigate the relationship among Working Memory Capacity (WMC) and Mathematical Performance (MP) of a sample of Pakistani students. A quantitative research approach was used to find out participants' WMC and to discover its relationship with their MP. A sample of 1186 participants' from fifty seven public sector secondary schools in Lahore, through multistage random sampling was selected for this research. Figure Intersection Test was used to measure WMC where as Mathematics Performance Test was used to measure MP. Data were analyzed by using computer software SPSS version 15. The results showed a notable difference in WMC and MP due to gender. Performance of male students on Mathematics Performance Test was better than the performance of female students in the same test. In addition, WMC and MP of English medium students was better than Urdu medium students. Overall, WMC was highly connected with MP. Three groups of WMC (low, medium and high) were significantly different from each other in scores of both Figure Intersection Test and Mathematics Performance Test. Low performance in mathematics is may be due to overloaded working memory; therefore, this study has recommended that curriculum designers may take advantage of this research while selecting mathematical topics for nine graders.

Keywords: Working memory capacity, mathematical performance, gender, English medium students, Urdu medium students

* Ph.D Scholar, Institute of Education and Research, University of the Punjab, Lahore
Email: tahirashehbaz@yahoo.com
**Ph.D Scholar, Institute of Education and Research, University of the Punjab, Lahore
***, Lecturer, Institute of Education and Research, University of the Punjab, Lahore

Introduction

Mathematics is an important subject in school education. Therefore, it is needed to explore factors affecting students' performance in this subject. The working memory capacity is viewed as a foundation for all cognitive processes that depend on temporary storage and it has a central role in gaining basic educational skills (Alloway & Alloway, 2010), therefore, it has an important role in mathematical performance in school level education (Alloway, 2006; Panaoura, 2007). The previous studies have argued close links between working memory capacity and mathematical performance (Alenezi, 2004; Holems & Adams, 2006). Working memory capacity is playing a vital role in the development of mathematical abilities.(Passolunghi & Siegel, 2004; Swanson & Beebe-Frankenberger, 2004). Working memory is responsible to preserve information active and available, so that, we can use it for different cognitive responsibilities (Crown, 2005; Hassin, 2005; Pickering, 2006 cited in Matlin 2009) including mathematical problem solving (Pezeshki, Alamolhodaei & Radmehr, 2011). In addition, Wilson and Swanson (2001) has explained that low working memory capacity has been found to be directly related to low computational abilities in arithmetic and low performance on mathematical problem solving in classroom (Alloway & Alloway, 2010). Researches have shown that students with extraordinary working memory capacity achieved significant higher results in mathematics test than that of low working memory capacity ones (Alamolhodaei, 2009; Pezeshki, Alamolhodaei & Radmehr,2011). Therefore, understanding students' low, medium and high working memory capacity in terms of assessment may help researchers to develop questions that don't place unnecessary stress on the students' working memory capacity (Alamolhodaei, 2009; Reid, 2002) which might be helpful for teachers and parents to encourage students to explain their own reasoning in front of their peers during class discussions in the subjects involving mathematical thinking (Reid, 2002).

Better understanding of gender differences regarding participants' working memory capacity will be useful in determining what works in developing new ways of teaching and learning mathematics for both male and female students (Hargreaves & Cristou, 2002).

The present study was conducted to study the participants' working memory capacity through the lens of their mathematical performance and to compare participants' lower higher and medium working memory capacity. Moreover, difference due to gender and medium of instruction (both English and Urdu medium) in participants' working memory capacity and mathematical performance was also explored.

Literature Review

Mathematics is believed as an important subject in school curriculum in Pakistan (Moenikia & Zahed, 2010; Alenezi, 2008). Therefore, it is important to investigate variables affecting mathematical performance(e.g. working memory capacity) that is allied to a range of cognitive activities like reasoning in mathematics (Kane & Engle, 2002).Researches on working memory capacity regarding gender differences may explain presence of differences in working memory capacity (Kaufman, 2007;Vecchi & Girelli, 1998; Vuontel, Steenari, Carlson, Koivisto, Fjalberg, & Aronen, 2003). Most of the researchers has argued significant gender differences (Kaufman, 2007; Vecchi & Girelli, 1998) and individual difference (Unsworth, & Engle, 2007; Beilock & Carr, 2005) in working memory capacity and argued the reason of differences in working memory capacity is linked to the differences in thinking ability (i.e. cognitive process) that includes verbal fluency reasoning and ability to perform dual task (e.g., Kane &Engle, 2002). Gross (2005) has argued that memory is an imaginary concept. He has further told that there are interrelated but distinct processes of memory. First process is registration, the sensory input transformation that allows it to convert into a memory. Similarly, second process is storage, which keeps information. Third one is retrieval that takes out information (i.e. already stored) from the memory store. Therefore, some cognitive models align brain functions, to some extent, with a computer, which is input and output device (Matiln, 2009).

There are three components of memory system: first is sensory memory second one is working memory capacity and third is long term memory. Sensory memory receives data through events, instructions and observations from the environment. It neglects a portion of sensory information and focus on what is imperative, exciting and sensational information. Our previous knowledge, beliefs, prejudices, preferences, likes and dislike all play an important role in development of perceptions (Johnstone, 1997). The working memory is a place in mind where new data is placed for a small time interval which actively process ongoing mental activities. Working memory or short term memory allow us to maintain information active and accessible so that we can use it for different cognitive tasks (Crown, 2005; Hassin, 2005; Pickering, 2006 cited in Matlin 2009). Working memory can be easily disrupted which may cause forgetfulness (Eysenck & Keane, 2004) because its capacity limitation is consisted of almost seven chunks and it holds information for limited time period of 20-30 seconds (Reed, 2000). Sweller, Van Merrienboer & Paas (1998) argued that human beings may be able to handle only two or three bits of information at a time on requirement to process rather than just holding information.

Baddeley (1986) illustrated that the working memory is a room where we intentionally think and perceive. Its capacity is limited and job is to hold and procedure the information within a specific time. According to Johnstone (1997), the stimuli and data confessed by the sensory memory is send to the temporary store (i.e. working memory) where it is processed and manipulated before being discarded or admitted for storage. According to Eysenck and Keane (2004), the working memory space in adults has a limited capacity of 7 ± 2 chunks. Chunking (i.e. dividing information into small bites) facilitates us to use this narrow space easily. Agreeing with Johnstone (1997) is that chunking be subject to some familiar framework of concepts, which help us to organize the new data. This information will store in long-term memory for unlimited time, after being processed in the working memory space. When we start to learn idea or concept, a number of ideas come into mind at first and these ideas after processing in working memory convert into a meaningful whole in the mind and store in long term memory (Al-Enezi, 2006).

In present research, literature has also thrown light on their forms of memory. Long-term memory is like a room where information is kept on permanent basis. It is like a library which lets them to get back for orientation and use (Eggan & Kauchak, 2007). The long-term memory gets data from working memory and keep it on a comparatively everlasting basis and can be retrieved when needed (Mangal, 2005). Working memory holds information which is active right now and long-term memory holds the data that is learned well and available when required. Once information is securely entered in this store, it may possibly remain there permanently. Working memory basically involves controlling and actively sustaining information to complete a cognitive task, e.g. mathematical word problems (Raghubar, Barnes & Hecht, 2010). Baddeley (1990) argues that working memory has a temporary system of holding and manipulating information during cognitive activities. Furthermore, working memory capacity may include reasoning, comprehension and problem solving (Engle, 2002). It has ability to control attention in case of distraction during memory process and cognitive tasks. Therefore some considerable evidences suggest that working memory maybe important for mathematical problem solving (Mayers, Redick, Chiffriller, Simone Terraforte, 2011). Adams and Hitch (1998) recommended that maximum of mental arithmetic depends upon working memory capacity. Therefore, there are significant associations between mental arithmetic and mathematical performance (Holmes &Adams, 2006). Moreover, Pezeshki, Alamolhodaei and Radmeh (2011) agreed that the students with higher capacity of processing in working memory space are comparatively good in solving word problems than those having low working memory capacity.

Swanson and Frankenberger (2004) argued that mathematical performance differs because human working memory capacity is different for everyone. Researchers have indicated that discrepancies in mathematics learning are connected to weak working memory capacity. findings of the Johnstone and El-Banna's (1989), studies observed that learners' mathematical problem solving demand should not exceed their working memory capacity limit; otherwise students' performance will decrease unless they find some approach which allows them to reconstruct the question according to their working memory capacity.

There are only few studies which indicate that individual differences mathematical performance in relation to working memory (Holmes & Adams, 2006; Swanson & Kim, 2007). Also, individual differences in the area of working memory capacity are extremely connected with performance in specific subjects (i.e. domain specific). Agreeing with Unsworth and Engle (2007), individual differences in relation to working memory capacity initiate from distinctions in the ability to keep information lively whereas being able to retrieve information stored in memory. Gathercoleet. al., (2004) investigated that working memory space is a forecaster of students' mathematical performance. Whereas working memory capacity does not depend upon background reasons such as early childhood education (Alloway, Gathercole & Pickering, 2006). Agreeing to Reid and Yang (2002), group work method is one of the useful ways to reduce issues related to working memory capacity. Although, an individual's working memory is his/her personal characteristics but still for some learners it is possible to decrease working memory overload by working in a group.

Alloway (2006) argued that working memory capacity is the mental workspace which may be used to perform cognitive actions (e.g. mathematical thinking, ability to perform dual task and verbal fluency) that require both processing and temporary storage (Engle & Kane, 2004). An example of working memory space is mental arithmetic like for a beginner student to solve a multiplication task mentally such as 4325×23 needs a space in mind for solution (Alloway, 2006). He further argues that the skill to do such action is narrow in mental workplace (i.e. working memory space) due to the involvement of dual task. Also due to the quick decay of information and poor link of long term memory we may not be able to put information in mind (Greary, Brown, & Samaranayake, 1991). Moreover, Parental involvement can also help students in their homework and studies (Batool & Raiz, 2019).

Mathematical performance may be foreknown by some foretelling reasons like working memory capacity (e.g. Alamolhodaei, 2009; Pezeshki, Alamolhodaei & Radmeh, 2011). Information about working memory capacity (i.e. a cognitive factor) affecting students' mathematical performance is imperative because poor working memory capacity may cause poor mathematical performance (Mousavi, Badarudin, & Malt, 2012; Alamolhodaei, 2009; Alloway, 2006; Holmes & Adam, 2006; Swanson, 2004; Wilson & Swanson, 2001). An examination of how students study, recall, practice and remember information may give answer to the question, how students can be helped to show good performance in mathematics by innovative teaching strategies (e.g. Mansor, Badarudin, Mat, 2011). The role of working memory capacity in teaching is point of discussion in present study.

Objectives of the Study

The main objectives of the study are to find out:

1. The relationship of students' working memory capacity and mathematical performance.
2. The differences regarding gender and medium of instruction in working memory capacity and mathematical performance.

Research Questions

1. Is there any relationship between participants' working memory capacity and mathematical performance?
2. Are there any differences among participants in relation to their working memory capacity and mathematical performance?
   a. Is there any gender based difference in participants' working memory capacity?
   b. Is there any gender based difference in participants' mathematical performance?
   c. Is there any difference between English medium and Urdu medium students' working memory capacity?
   d. Is there any difference between English medium and Urdu medium students' mathematical performance?

Method

The study used quantitative research method to survey the relationship between participants' working memory capacity as well as the variation of the data in relation to participants' gender and medium of instructions at secondary schools. By multistage random sampling fifty seven Government high schools were selected, from which 1186 grade nine students (62% boys and 38% girls) joined this study. Participants were selected from both English and Urdu medium (74% English medium and 36% Urdu medium) sections (classes) from public sector schools. It was expected that grade 9 students (mean age =15 years) in different sections either Urdu or English medium were formed a homogenous group. For avoiding the number of students in any section to be more or less than the others, every section was a sub-group of the population and it was formed a sample by taking particular numbers of students from every section.

Measures to assess Working Memory Capacity and Mathematical Performance

The study has used the standardized Figure Intersection Test (FIT) to measure the working memory capacity which was initially designed by Pascual-Leone (1970). Recently it was used by Ali (2008) in her study conducted in Lahore (Pakistan).In figure intersection test (FIT) there were two sets A&B of simple geometrical shapes. The Set B consists of the separate shapes whereas Set A consists of the same shapes overlapping with some common area inside all the shapes. What the participants had to do was to shade in the area where all these shapes intersect each other, in the test set (Set A). A confusing unrelated shape that was not present in Set B was included in the Set A in some items. The task became more complex with increase in number of shapes. There were total 20 items in this test. The number of shapes in each question was varied from 2 to 8 shapes. The scores of an item were same as the number of shapes in the Set B, if the item is marked correctly. Thirty seconds were given to answer each item. A detailed instruction sheet with two solved examples was attached with the test for the convenience. Its reliability was found 0.78 that was appropriate.

The researcher also designed a test to measure mathematical performance. Mathematics performance test was constructed for grade nine students. This test was constructed by the help of textbook used in public sector secondary schools in Lahore. All the questions were selected from their textbook with minor changes. Marks distributions were according to the difficulty level of the questions for grade nine students. Mathematics performance test was translated into Urdu for Urdu medium students. After the preparation, the test was validated and piloted by split half reliability (0.81).

Results

The mean and standard deviation of figure intersection test is 44.61 and 26.03. Similarly, mean and standard deviation of mathematics performance test is 16.98 and 12.96.

Table 1
Correlation between Figure Intersection Tests and Mathematics Performance test

N	Pearson correlation	Sig
1179	0.826	0.004*

*Correlation is significant at 0.05 levels.

Participants' working memory capacity and mathematical performance were positively correlated.

In the present study, descriptive statistics were used to describe the basic features of the data and simple summaries about the sample. Data obtained from figure intersection test (FIT) was distributed in three groups shown in figure below.

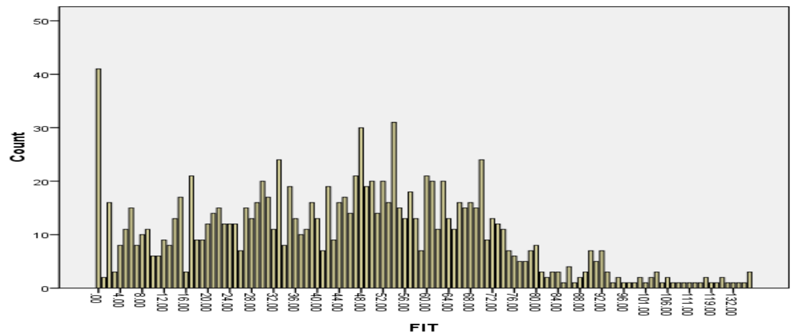

Figure1: Distribution of participants according to their Working Memory Capacity test scores

Explanation of categories is given below:

Participants who scored more than [Mean+ ½(standard deviation)], were considered as with high working memory capacity group (28%).The rest who scored between high and low working memory capacity were labeled as participants with medium working memory and they form the largest proportion (42%) of the participants. Participants of the study who scored less than [Mean -½(standard deviation)] in the FIT were classified as participants with low working memory capacity and they form 30% of the participants.

Table 2
ANOVAs

Groups	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2320.619	2	1160.309	6.972	.001*
Within Groups	195713.351	1176	166.423		
Total	198033.969	1178			

*Significant at 0.05 levels.

Above table reveals that (F=6.97, 0.001<0.05) three groups (High, Medium, Low) of participants' working memory capacity are significantly different from each other.

Table 3
Post Hoc

(I) fit	(J)fit	Mean Difference (I-J)	Std. Error	Sig.(p)
1	2	-1.73555	.91369	.058
	3	-3.58691*	.96109	.000
2	1	1.73555	.91369	.058
	3	-1.85136*	.90311	.041
3	1	3.58691*	.96109	.000
	2	1.85136*	.90311	.041

$p^* < 0.05$

Table 3 shows that the difference between group 1 and 3 is greater as compared to group 1 and 2. This indicates that performance at mathematics test of students with high working memory capacity was improved than low working memory capacity ones.

Table 4
Comparison of High, Medium and Low Working Memory Capacity (WMC) with mathematical performance of participants

Working memory capacity (WMC)	Mathematics marks (%) English medium	Mathematics marks (%) Urdu medium
Higher WMC	63	61
Medium WMC	49	48
Lower w WMC	35	38

Table 4 shows that there is a noteworthy difference of mathematical performance due to participants' high, medium and low working memory capacity found in this study.

Table 5

Comparison of Working Memory Capacity (both Male and Female)

Group	*N*	*Mean*	*Mean Difference*	*t*	*Sig*
Male	733	48.314	8.86	5.79	0.00
Female	446	39.448			

**Difference is significant at 0.05 levels.

The t value is notable (t= 5.79, 0.000 <0.05). Hence, it can be determined that there is a noteworthy difference in working memory capacity of male and female participants. Male participants of this study have higher working memory capacity than female participants.

Table 6

Comparison of Mathematical Performance Test (both Male and Female)

Group	N	Mean	Mean Difference	*t*	Sig
Male	733	17.67	2.78	2.21	0.02
Female	446	14.89			

*Difference is significant at 0.05 levels.

The significance of t value (t=2.21, 0.02 <0.05) is evidence from table 6. Therefore, it can be said that there is a notable difference in mathematical performance of (both male and female) participants. Mathematical performance of male participants is better than female participants.

Table 7

Comparison of Working Memory Capacity of Urdu and English Medium students

Group	N	Mean	Mean Difference	*t*	Sig
Urdu	876	42.014	11.50	6.80	0.00
English	303	53.548			

**Difference is significant at 0.05levels.

The t value is significant (t= 6.80, 0.000 <0.05) in table 7. Later, it can be said that there is a noteworthy difference in participants' working memory capacity based on their gender. Furthermore, male students participated in this study have working memory capacity higher than female students of this study.

Table 8

Comparison of Math Performance Test of Urdu and English Medium Students

Group	N	Mean	Mean Difference	t	Sig
Urdu	876	15.08	8.87	2.21	0.00
English	303	22.51			

**Difference is significant at 0.05 levels.

The t value is significant (t= 2.21, 0.000 <0.05) in table 8. Therefore it can be observed that there is a noteworthy difference in participants' mathematical performance (both Urdu medium and English medium students).

Discussion

The study was designed to explore the connection of students' working memory capacity with their mathematical performance as well as comparisons of gender differences and medium of instruction with respect to participants' working memory capacity and mathematical performance.

The present study has looked into the correlation of participants' working memory capacity with their mathematical performance. The correlation analysis of data shows significant correlation between these two variables. This recent finding is similar to those of some previous conceptions about the relationship of students' working memory capacity and their mathematical performance (Alloway & Alloway, 2010; Alloway, 2009; Holmes & Adams, 2006). The present study adds up more suggestions on the contribution of working memory capacity in mathematical performance. Researchers have also provided evidence for an involvement of working memory capacity in cognitive tasks which are responsible for problem solving in mathematics (see Alamoihodaei, 2009; Swanson, 2004). Various studies have reported noteworthy correlation between both variables of the study: first the mathematical performance and second the working memory capacity (e.g. Holmes & Adams, 2006; Swanson & Frankenberger, 2004). This implies that participants' working memory capacity may affect their mathematical performance which is allied with previous researches (e.g. Mousavi, Badarudin, & Malt, 2012; Wilson & Swanson, 2001).

Another significant finding of this study was that there are significant differences in the working memory capacity of male and female participants. The working memory capacity of male participants is better than that of female participants which is consistent with analysis conducted by some previous researches (Linn & Peterson, 1985). The available studies on the working memory capacity (e.g. Kaufman, 2007; Vuontela,V., Steenari, M. R., Carlson, S., Koivisto, J., Fjalberg, M., & Aronen, T. E., 2003; Vecchi & Girelli, 1998) has also shown gender differences regarding students' working memory capacity. According to some, recent investigations by Schmader and Johns, 2003, lower working memory capacity of female students as compare to male students is may be a result of the stereo type threat on working memory capacity. Schmader study further explains that a decrease in working memory capacity may arbitrate the effect of stereotype threat on female students' mathematical performance. Consequently, in present study stereotype threat may affect female students' working memory capacity. This also seems evident from previous studies that there are gender differences among students working memory capacity may have unique impact on mathematical performance (e.g. Alenezi, 2004).

A significant difference was also seen between male and female participants' mathematical performance. There was a higher mean of mathematical performance in male students. This was found in line with Alloway's (2009) findings in which the mathematical performance of male students is better than female students. Some other researchers has also reported gender gap regarding mathematical performance (e.g. Andreescu, Gallian, Kane, & Mertz, 2008)

The present study has also addressed the differences in working memory capacity and mathematical performance of grade nine students in relation to different mediums of instruction (English and Urdu medium); with a reasonable sample size, significant differences were found in students working memory capacity and mathematical performance. We have already discussed that students in English medium classes (sections) are with high working memory capacity than Urdu medium classes (sections) that may be the reason of their better mathematical performance than Urdu medium students in sample.

Overall, the findings of current study propose that working memory capacity may possibly have significant relationship on mathematical performance. It also supports previous arguments that working memory capacity is a remarkable forecaster of participants' mathematical performance (e.g. Ashcraft & Krause, 2007; Alamolhodaei, 2000; 2009; Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H., 2004). Moreover, gender is an important contributor to students' academic performance (McCoy, 2005).

Conclusion

Overall the practical implications of this finding may suggest that if we wish to strengthen mathematical learning we should identify students' working memory capacity (Alloway, 2010). There are growing evidences that working memory capacity might be enhanced by some trainings (see Jaeggi, Buschkuehl, Jonides, & Perrig, 2008), it means that identification of students' working memory capacity is very important because it may help curriculum designers to design curriculum to enhance students' working memory capacity. It also may be helpful for teachers and parents to manage mathematical exercises according to students' working memory profile. Any instructional practices when dealing with information, overlook working memory capacity limits is unlikely to be operative (Kirschner, Sweller, & Clark, 2006), therefore, teachers may use this finding to adjust their pedagogy to avoid overload in working memory capacity (Alloway, 2006; Dehn, 2008) and to improve teaching learning process. Wilson, Swanson and Lee (2001) observed that almost every mathematical tasks involves working memory capacity, therefore, we come to a close prediction that students' working memory capacity is directly proportional to their mathematical performance and feedback can also effect positively on students performance (Batool & Akhter, 2019)

Recommendations

One might also explore the relationship of working memory capacity of diverse population with their mathematical performance. Another, needing exploration is why the school mathematics in Urdu medium participants is creating problems. One might also consider the effect of working memory capacity (WMC) of elementary school on their performance in any subject by using experimental research design.

References

Adams, J. W., & Hitch, G. J. (1998). Children's mental arithmetic and working memory. *The Development of Mathematical Skills*, 153-173.

Alamolhodaei, H. (2009). A working memory model applied to mathematical word problem solving. *Asia Pacific Education Review*, *10*(2), 183-192.

Al-Enezi, D. (2004). *Difficulties associated with teaching and learning mathematics: A study of psychological factors affecting pupils' performance.* Science Education Centre. Glasgow, Glasgow University.

Alenezi, D. (2008). *A study of learning mathematics related to some cognitive factors and to attitudes* (Doctoral dissertation). University of Glasgow

Ali, A. A. (2008). *Perceptions, difficulties and working memory capacity related to mathematics performance* (Doctoral dissertation). University of Glasgow

Alloway, T. P. (2006). How does working memory work in the classroom?. *Educational Research and Reviews*, *1*(4), 134-139.

Alloway, T. P. (2009). Working memory, but not IQ, predicts subsequent learning in children with learning difficulties. *European Journal of Psychological Assessment*, *25*(2), 92-98.

Alloway, T. P. (2010). Working memory and executive function profiles of individuals with borderline intellectual functioning. *Journal of Intellectual Disability Research*, *54*(5), 448-456.

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, *106*(1), 20-29.

Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable?. *Child Development*, *77*(6), 1698-1716.

Andreescu, T., Gallian, J. A., Kane, J. M., & Mertz, J. E. (2008). Cross-cultural analysis of students with exceptional talent in mathematical problem solving. *Notices of the AMS*, *55*(10), 1248-1260.

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin &Review*, *14*(2), 243-248.

Baddeley, A. (1986). *A working memory*. London, Oxford University Press.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(1), 417-423.

Baddeley, A. D. (1990). *Human memory: Theory and Practice*. Hove: Lawrence Erlbaum Associates Ltd.

Beilock, S. L., &Carr, T. H. (2005).When high-powered people fail: Working memory and "choking under pressure" in math. *Psychological Science*, *16*(2), 101-105.

Batool, T., & Riaz, J. (2019). Variations in parental participation in curricular and Co-curricular activities of university students. *Global Social Sciences Review 4*(4), 239 – 249.

Batool, T. & Akhter, M. (2019). Feedback effects on secondary school students' achievement in Mathematics. *Global Social Science Review*, *4*(3), 123-134.

Dehn, M. J. (2011). *Working memory and academic learning: Assessment and intervention*. John Wiley & Sons.

Eggen & Kauuchak. (2007). *Educational psychology: Windows on classroom.* Upper Saddle River: Pearson Merrill Prentice Hall.

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19-23.

Eysenck, M. W. (2004). *Cognitive psychology. A student's hand book*. New York: Psychology press.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *18*(1), 1-16.

Geary, D. C., Brown, S. C., & Samaranayake, V. A. (1991). Cognitive addition: A short longitudinal study of strategy choice and speed-of-processing differences in normal and mathematically disabled children. *Developmental Psychology*, *27*(5), 787.

Gross, R. (2005). *Psychology: The science of mind and behavior* (5th ed.). London: British Library Cataloguing in Publication Data.

Hargreaves, J., & Christou, A. (2002). An institutional perspective on QAA subject benchmarking. *Quality Assurance in Education*, *10*(3), 187-191.

Holmes, J., & Adams, J. W. (2006). Working memory and children's mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology*, *26*(3), 339-366.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, *105*(19), 6829-6833.

Johnstone, A. H. (1997). And some fell on good ground. *University Chemistry Education. 1*, 8-13.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing demand. *Journal of Chemical Education*, *70*(9), 701.

Johnstone, A. H., & El-Banna, H. (1989). Understanding learning difficulties: A predictive research model. *Studies in Higher Education*, *14*(2), 159-168.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin &Review*, *9*(4), 637-671.

Kaufman, S. B. (2007). Sex differences in mental rotation and spatial visualization ability: Can they be accounted for by differences in working memory capacity? *Intelligence*, *35*(3), 211-223.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86.

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, 1479-1498.

Mangle, S. K. (2005). *Advanced educational psychology*. New Delhi: Prentice Hall of India.

Mansor, N., Badarudin, M. I., & Mat, A. C. (2011).Teachers perspective of using English as a medium of instruction in mathematics and science subjects. *Online Submission*, *4*(2), 129-138.

Matlin, W. M. (2009). *Cognitive psychology*. New Jersey: John Wiley & Sons.

Mayers, L. B., Redick, T. S., Chiffriller, S. H., Simone, A. N., & Terraforte, K. R. (2011). Working memory capacity among collegiate student athletes: Effects of sport-related head contacts, concussions, and working memory demands. *Journal of Clinical and Experimental Neuropsychology*, *33*(5), 532-537.

McCoy, L. P. (2005). Effect of demographic and personal variables on achievement in eighth grade algebra. *Journal of Educational Research, 98*, 131-135.

Moenikia, M., & Zahed-Babelan, A. (2010). A study of simple and multiple relations between mathematics attitude, academic motivation and intelligence quotient with mathematics achievement. *Procedia-Social and Behavioral Sciences, 2*(2), 1537-1542.

Mousavi, S., Radmehr, F., & Alamolhodaei, H. (2012). The role of mathematical homework and prior knowledge on the relationship between students' mathematical performance, cognitive style and working memory capacity. *Electronic Journal of Research in Educational Psychology*. *10*(3).

Panaoura. A. (2007). The interplay of processing efficiency and working memory with the development of metacognitive performance in mathematics. *The Montana Mathematics Enthusiast*, *4*, 31-52.

Passolunghi, M. C., & Siegel, L. S. (2004). Working memory and access to numerical information in children with disability in mathematics. *Journal of experimental child psychology*, *88*(4), 348-367.

Pezeshki, P., Alamolhodaei, H., & Radmehr, F. (2011). A predictive model for mathematical performance of blind and seeing students. *EducRe, 2*, 864-873.

Raghubar, K. P., Barnes, M. A., & Hecht, S A. (2010).Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences 20*, 110–122.

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Perspective in Academic Gaming and Simulations*, 1, 92-97.

Reed, S. K. (2000). *Cognition, theory and application*. New York: Wadsworth Thomson Learnig.

Reid, N. (2009). Working memory and science education: Conclusions and implications. *Research in Science & Technological Education*, *27*(2), 245-250.

Schmader, T., & Johns, M. (2003). Converging evidence that stereotype threat reduces working memory capacity. *Journal of Personality and Social Psychology*, *85*, 440 −452.

Swanson, H. L., & Lee, S. C. (2001). Mathematical problem solving and working memory in children with learning disabilities: both executive and phonological processes are important. *Journal of Experimental Child Psychology, 79*, 294-321.

Swanson, H., & Beebe-Franken berger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, 96, 471-491.

Swanson, L., & Kim, K. (2007). Working memory, short-term memory and naming speed as predictors of children's mathematical performance. *Intelligence, 35,*151–168.

Swanson, H, L. (2004). Working memory and phonological processing as predictors of children's mathematical problem solving at different ages. *Memory and Cognition*, *32*, 648-661.

Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251-296.

Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, *114*, 104-132.

Vecchi, T., & Girelli, L. (1998). Gender differences in visuo-spatial processing: The importance of distinguishing between passive storage and active manipulation. *Acta Psychologica, 99,* 1−16.

Vuontela,V., Steenari, M. R., Carlson, S., Koivisto, J., Fjalberg, M., & Aronen, T. E. (2003). Audio spatial and visuospatial working memory in 6–13 year old school children. *Learning& Memory*, *10*, 74–81.

Wilson, K. M., & Swanson, L. (2001). Are mathematics disabilities due to a domain-general or a domain-specific working memory deficit? *Journal of Learning Disabilities, 34,* 237-248.