Journal of Elementary Education
Volume 27, No. 2, pp. 71-83

Gender, Sector and Grade Level differences in Mathematical and Cognitive Abilities of Students at Elementary Schools in Lahore

Muhammad Abiodullah*, Shafiqur Rehman**and Muhammad Aslam***

Abstract

Mathematical and cognitive abilities have special role in information and technological era. These abilities help children to perform routine activities efficiently. Use of mathematical and cognitive abilities make life more successful and more efficient. This research was conducted to determine cognitive and mathematical abilities of students studying at elementary level. Quantitative approach was used to conduct this study. For this purpose, 941 students, 481 (50.6%) female and 470(49.4%) male, were selected from seven schools in Lahore City. Thessaloniki Maths test, and Volume and Heaviness Task were used for assessing mathematical and cognitive abilities of students respectively. t-test was conducted to find difference in mathematical and cognitive abilities of students regarding gender and sector while One-way ANOVA was applied to see difference in mathematical and cognitive abilities of students of different grades. Results indicate significant differences between male and female students in their mathematical ability on grades V and VI while there was also significant difference between male and female students in cognitive ability on grades IV and V. Results related to the sector show significant difference in mathematical ability of students of private and public schools of grades IV to VIII while results related to cognitive ability show significant difference in students of public and private schools of grades IV, V and VIII. This study implicates that Mathematics teachers should use wide range of techniques and material in mathematics classroom. This study would help to assess abilities of students and align teaching with these abilities.

Keywords: Mathematical ability, cognitive ability, element level, Thessaloniki maths test, Volume and heaviness task

*Assistant Professor, Institute of Education and Research, University of the Punjab, Lahore.
Email: abiodullah.ier@pu.edu.pk
** Lecturer, Institute of Education and Research, University of the Punjab, Lahore

Introduction

The word ability is commonly used in academic and non-academic communities. Ability is the potential capacity to perform a specific task efficiently. It may be defined as "A capacity to accomplish a task at the present moment" (Matsumoto, 2009, p.20). It can also be defined more precisely as mental or physical characteristic of a person to do tasks in a given situation. The competence to understand problems, issues or ideas and try to find solution are domains of ability. Other domains of ability are general reasoning, verbal reasoning, induction, and deduction (Busato, Prins, Elshout, & Hamaker, 2000). Mathematical and cognitive abilities have special role in information and technological era (Dede, 2008).

Mathematical ability is a psychological construct that helps to answer mathematical activities and leads to success in mastery of mathematics. It is collection of different abilities like ability to extract formal structure from statement of mathematical problem, ability to generalize numerical examples to algebraic equation, ability to operate with symbols and numbers (Krutetskii, 1976). Vilkomirand and Donoghue (2009) concluded that mathematical abilities other than logical thinking and powerful intelligence are required to become a good mathematician. Kramarski, and Mevarech (2003) observed that mathematical thinking operates in the presence of identification, comparison, reasoning and power of thinking.

Cognitive ability is mental attribute of a person that helps them to do a task successfully. It consists of processes such as knowing, understanding, recognizing, judging, visualizing, imaging and reasoning. If a person does not use one's cognitive ability, it may decrease. Cognitive ability can be improved with proper practices over the time (Dreyfus, 1991). Use of mathematical and cognitive abilities make life more successful and more efficient (Resnick, 1987).

The topic of sex differences in cognitive abilities is controversial among educationists, sociologists and public policy makers (Eagly & Mitchell, 2004; Miller & Halpern, 2014) because research studies have not yet concluded that whether the difference exits or not. According to Nyborg (2015), males and females do not differ in their general intelligence and sex differences were found in special abilities. The study of Halpern and Lamay (2000) concluded that males are good on mental rotation and special perception while females are better on verbal fluency and grammar. Males are more representative in science, technology, engineering, and mathematics than women (Hill, Corbett, & St. Rose, 2010). The Program for International Student Achievement (PISA) shows gender difference in mathematics and science for some nations but not for all

(Else-Quest, Hyde, & Linn, 2010; Guiso, Monte, Sapienza, & Zingales, 2008; Reilly, 2012). Reilly, Neumann and Andrews (2016) reflected that masculine role are more associated with mental rotation, spatial perception, and spatial visualization and feminine role are associated with phonological verbal fluency, synonym generation, and grammar and language usage. The development in mathematical and cognitive abilities for different grades is another interesting area for educational researchers. The score in mathematical reasoning in 4^{th} grade students was higher than the 3^{rd} grade students (DeLay, Laursen, Kiuru, Poikkeus, Aunola, & Nurmi, 2015).

The purpose of the study was to determine and compare the level of mathematical and cognitive abilities of students at elementary level. The study was undertaken to provide answers to the questions related to difference in mathematical and cognitive abilities of students on the basis of gender, sector and grade levels.

Objective of the Study

The objectives of the study were to**:**

- determine the level of mathematical ability of students at elementary level.
- determine the level of cognitive ability of students at elementary level.
- Compare the levels of mathematical ability of elementary students on the basis of gender, sector and grade level.
- Compare the levels of cognitive ability of elementary students on the basis of gender, sector and grade level.

Research Hypotheses

To achieve the research objectives, following generalize hypotheses were formulated:

- There was no statistically significant difference in mathematical ability for female and male students.
- There was no statistically significant difference in cognitive ability for female and male students.
- There was no statistically significant difference in mathematical ability for private and public students.
- There was no statistically significant difference in cognitive ability for private and public students.
- There was no statistically significant difference in mathematical ability for different grades
- There was no statistically significant difference in cognitive ability for different grades.

Method and Procedure

The study was quantitative in nature and cross-sectional survey design was used to collect the data. The students studying at elementary level (IV-VIII) in Lahore schools was the population of the study. Total public schools in public sector was 1219 out of which 613 were male schools and 606 female schools. Half million students were enrolled in all schools.

Nine hundred fifty-one students (481 females and 470 males) were selected from seven schools. Schools were selected by convenience sampling. All students were selected from one section, in case of more than one section, the section was selected by random sampling. Details of sample size are given below.

Table 1
Distribution of Sampled Students from Seven Selected Schools

	Grade					Total
	IV	V	VI	VII	VIII	
School 1	-	-	30	40	21	91
School 2	27	39	29	25	28	148
School 3	30	32	43	46	74	225
School 4	12	24	38	30	12	116
School 5	33	42	22	36	32	165
School 6	-	-	19	13	25	57
School 7	29	29	38	27	26	149
Total	131	166	219	217	218	951

Instruments

Two instruments were used; 1) Thessaloniki Maths Test was used for assessing mathematical ability 2) Volume and Heaviness Task was used for assessing cognitive ability of students. Thessaloniki Maths Test consisted of three parts, i.e. Use of basic maths operations, Algebra and Proportionality. It covers Piagetian levels from middle concrete to mature formal. The internal consistency of the test is 0.73. Volume and Heaviness Task was based on the child construction of quantities. Its range was from concrete operational thinking to early formal thinking. The internal consistency of the test is 0.85.

Data Collection

For data collection, list of schools was obtained from the Directorate of Public Instruction (DPI), Punjab, Lahore. Seven schools were selected by convenience sampling. Head teacher of each school was contacted through telephone. After negotiation with the heads, school visit schedule was finalized. Two days were spent in one class to administer two instruments. Total fourteen working days were spent to collect data from the seven schools. Both instruments were administered by the researcher personally.

Data Analysis

After collection of the data, answer sheets were arranged and coded. Data were entered to SPSS grid sheet and cleaned. Descriptive and inferential statistics were employed. To determine and compare mathematical and cognitive abilities of elementary students, different parametric tests were applied. t-test was conducted to find statistically significant difference in mathematical and cognitive abilities of students regarding gender and sector. One-way ANOVA was conducted to see statistically significant difference in mathematical ability and cognitive ability of students for different grades.

Results

Table 2

Mean Scores in Mathematical Ability for Male and Female Students (N=951)

Grade	Female			Male			Independent samples t-test		Effect size
	n	*M*	*SD*	*n*	*M*	*SD*	*t*-value	*p*-value	(Cohen's *d*)
IV	71	3.91	0.75	60	3.75	.58	1.23	.221	0.23
V	85	4.22	0.87	81	3.88	.58	2.89**	.004	0.46
VI	89	5.50	1.08	130	4.01	.88	11.06***	<.001	1.51
VII	103	4.62	1.13	114	4.73	.71	.828	.409	0.12
VIII	133	4.75	0.92	85	4.89	.95	1.06	.292	0.15
Total	481	4.63	1.09	470	4.29	.895	5.27***	<.001	0.34

p<.01,*p<.001

Table 2 shows difference in mathematical ability for male and female students of grades IV-VIII. The results of independent sample t-test indicate that there was no statistically significant difference in mathematical ability for female and male students of grades IV, VII, VIII (p>.05) but there was statistically significant difference in mathematical ability for female and male students of grades V, VI ($p<.05$). The mean score of female students ($M=4.22$, $SD=.87$) was greater than that of the male students ($M=3.88$, $SD=.58$) of grade V. The mean score of female students ($M=5.50$, $SD=1.08$) was greater than that of the male students ($M=4.01$, $SD=.88$) of grade VI. There was also

statistically significant difference in mathematical ability for female and male students in aggregate score of all grades (t=5.27, p<.001). The results indicate that mean score of female students (*M*=4.63, *SD*=1.09) was greater than that of the male students (*M*=4.29, *SD*=.895). The value of effect size (Cohen's *d*) in all grades varies from 0.12 to 1.51. The standard values for Cohen's *d* are weak=0.2, medium=0.5, large= 0.8. The effect size for grade VI was large, the effect size for grade IV, V was medium and for grade VII and VIII was weak for gender difference on mathematical ability.

Table 3

Mean Scores in Cognitive Ability for Male and Female Students (N=951)

Grade	Female			Male			Independent samples t-test		Effect size
	n	*M*	*SD*	n	*M*	*SD*	*t* value	*p* value	(Cohen's *d*)
IV	71	4.48	0.65	60	3.86	0.77	5.00***	<.001	0.87
V	85	4.48	0.74	81	4.02	0.81	3.85***	<.001	0.59
VI	89	4.62	0.71	130	4.40	0.89	1.94	.054	0.27
VII	103	4.83	0.86	114	4.79	0.94	0.334	.739	0.04
VIII	133	5.21	1.49	85	5.07	1.03	0.740	.460	0.11
Total	481	4.76	1.07	470	4.47	1.00	4.25***	<.001	0.28

***p<.001

Table 3 reveals the significant difference in cognitive ability for female and male students of grades IV-VIII. The results of independent sample t-test indicate that there was no statistically significant difference in cognitive ability for female and male students of grades VI, VII, VIII (p>.05). There was statistically significant difference in cognitive ability for female and male students of grades IV, V (*p*<.05). The mean score of female students (*M*=4.48, *SD*=.65) was greater than that of the male students (*M*=3.86, *SD*=.77) of grade IV. The mean score of female students (*M*=4.48, *SD*=0.74) was greater than that of the male students (*M*=4.02, *SD*=0.81) of grade V.

There was statistically significant difference between male and female students in aggregate mean scores for all grades (t=4.25, p<.001). The results indicate that the mean score of female students (*M*=4.76, *SD*=1.07) was greater than that of the male students (*M*=4.47, *SD*=1.00). The value of effect size (Cohen's *d*) in all grades varies from 0.04 to 0.87. The effect size for grade IV was large, the effect size for grade V, VI was medium and for grade VII and VIII was weak for gender difference in cognitive ability.

Table 4

Mean Scores in Mathematical Ability for Private and Public School Students (N=951)

Grade	Private			Public			Independent samples t-test		Effect size
	n	*M*	*SD*	N	*M*	*SD*	*t*-value	*p*-value	(Cohen's *d*)
IV	59	4.07	.64	72	3.57	.62	4.16***	<.001	0.79
V	61	4.48	.88	105	3.79	.53	6.21***	<.001	0.95
VI	130	5.19	1.18	89	3.81	.69	9.81***	<.001	1.43
VII	126	5.06	.83	91	4.14	.80	8.12***	<.001	1.13
VIII	146	4.87	.99	72	4.68	.79	1.41	.161	0.21
Total	522	4.84	1.023	429	3.99	.77	14.34***	<.001	0.94

***p<.001

Table 4 shows statistically significant difference in mathematical ability for private and public school students of grades IV-VIII. The results of independent sample t-test indicate that there was no statistically significant difference in mathematical ability for private and public school students of grade VIII (p>.05). There was statistically significant difference in mathematical ability of private and public school students of grades IV- VII ($p<.05$). The mean score of private school students was greater than that of the public school students of grades IV-VII. In all grades, private school students' mathematical ability was better than public school students' mathematical ability, the mean difference varies from 0.19 to 1.38.

The value of effect size (Cohen's *d*) in all grades varies from 0.12 to 1.51. The effect size for grades IV-VII was large, and for grade VIII was weak for sector difference on mathematical ability.

Table 5

Mean Scores in Cognitive Ability for Private and Public School Students (N=951)

Grade	Private			Public			Independent samples t-test		Effect size
	n	*M*	*SD*	*N*	*M*	*SD*	*t*-value	*p*-value	(Cohen's *d*)
IV	59	4.01	0.91	72	4.30	0.71	2.21*	.029	0.36
V	61	4.70	0.72	105	4.02	0.82	5.20***	<.001	0.88
VI	130	4.40	0.81	89	4.63	0.80	1.74	.084	0.29
VII	126	4.70	1.01	91	4.93	0.80	1.84	.067	0.25
VIII	146	5.02	1.31	72	5.51	1.41	2.99*	0.04	0.36
Total	522	4.59	1.06	429	4.64	1.03	.729	0.467	0.05

*p<.05, **p<.01, ***p<.001

Table 5 shows statistically significant difference in *cognitive ability for* private and public school students of grades IV-VIII. The results of independent samples t-test indicate that there was no statistically significant difference in cognitive ability of private and public school students of grades VI-VII and overall ($p>.05$). There was statistically significant difference in cognitive ability for private and public school students of grades IV, V and VIII ($p<.05$). The mean score of private school students was greater than that of the public school students of grade V.

The results indicate that mean score of private school students of grade V (M=4.70, SD=0.72) was greater than that of the public school students (M=4.02, SD=0.82). The results also indicate that mean score of private school students on grade IV (M=4.01, SD=0.91) was less than that of the public school students (M=4.30, SD=0.71). The results indicate that mean score of private school students of grade VIII (M=5.02, SD=1.31) was less than that of the public school students (M=5.51, SD=1.41).

The value of effect size (Cohen's d) in all grades varies from 0.05 to 0.88. The effect size for grade V was large, and for grades IV, VI, VII, VIII were medium, and weak for overall score for sector difference on cognitive ability.

Table 6

Mean Scores of Students' Mathematical Ability in Different grades (N=951)

Grade	Age (years)	n	*M*	*SD*	% increase in Mean	*F*(4,946)	*p*-value
IV	9.9	131	3.83_{a}	0.67	-	33.85	<.001
V	11.6	166	4.03_{b}	0.76	5.2		
VI	12.5	219	$4.62_{a,b,c}$	1.22	14.6		
VII	13.2	217	$4.68_{a,b,d}$	0.93	1.3		
VIII	14.0	218	$4.79_{a,b,e}$	0.93	2.4		

Note: In column 4 means are given. Means sharing same subscripts are significantly different

Table 6 shows the change in mathematical ability of students with the change of grades. The mathematical ability increases as grade level increases. There was no statistically significant difference in mathematical ability for grades IV and V students but there was significant difference in mathematical ability among students of grades VI, VII and VIII.

Table 7

Mean Scores of Students' Cognitive Ability in Different Grades (N=951)

Grade	Age (years)	Cognitive Ability			% increase in Mean	$F(4,946)$	p-value
		n	*M*	*SD*			
IV	9.9	131	4.17_{a}	0.82	-	27.90	<.001
V	11.6	166	4.25_{b}	0.81	1.9		
VI	12.5	219	$4.49_{a,b}$	0.83	5.6		
VII	13.2	217	$4.81_{a,b}$	0.90	7.1		
VIII	14.0	218	$5.09_{a,b}$	1.39	5.8		

Note: In column 4 means are given. Means sharing same subscripts are significantly different

Table 7 shows the development in cognitive ability of students with the change of grades. The cognitive ability increases as grade level increases. There was no statistically significant difference in cognitive ability between grade IV and V students but there was significant difference among VI, VII and VIII grade students.

Table 8

Percentage of students at different Piagetian stages (N=951)

	Age (years)				
	10	11	12	13	14
2A	14%	31%	54%	74%	97%
2A/2B	8%	19%	35%	51%	70%
2B	3%	7%	15%	23%	38%
2B*	-	1%	2%	5%	11%
3A	-	-	-	-	2%
3A/3B	-	-	-	-	1%
3B	-	-	-	-	1%

Note: 3B= Formal generalization, 3A/3B= Mature formal, 3A= Early formal,
2B*= Concrete generalization, 2B= Mature concrete, 2A/2B= Mid concrete, 2A= Early concrete

Table 8 reveals the distribution of cognitive levels among students of different grades. The level 2A (Early concrete) is lowest level and 3B (formal generalization) is highest at cognitive level. The majority of students of grade IV falls between 2A to 2B while students of grades V, VI, VII and VIII gradually moved up towards higher level of cognitive ability.

Discussion

Mathematical and cognitive abilities are core elements for academic and professional growth. The content of mathematics taught in schools is expanded horizontally and vertically on the assumption that students who have improved their mathematical and cognitive abilities can easily face more complex and difficult mathematical problems. The main objective of this study was to provide evidence to support this assumption. Further this assumption was used to link the evidence logically with the following hypotheses.

- There was no statistically significant difference in mathematical ability for female and male students.
- There was no statistically significant difference in cognitive ability for female and male students.
- There was no statistically significant difference in mathematical ability for private and public students.
- There was no statistically significant difference in cognitive ability for private and public students.
- There was no statistically significant difference in mathematical ability for different grades.
- There was no statistically significant difference in cognitive ability for different grades.

For collection of data to be used as evidence to support or reject the hypothesis, a sample of male and female students of grades VI-VIII from public and private elementary schools were selected by convenience sampling. Then the data was analysed using SPSS. By using t-test and ANOVA, the significance of difference in mathematical ability were tested. In the light of these tests, the following hypotheses were accepted on the basis of groups within the total sample.

- There was no statistically significant difference in mathematical ability for female and male students on grades IV, VII, VIII.
- There was no statistically significant difference in cognitive ability for female and male students on grades VI, VII and VIII.
- There was no statistically significant difference in mathematical ability for private and public students on grade VIII.
- There was no statistically significant difference in cognitive ability for private and public students on grades IV, VI and VII.
- There was no statistically significant difference in mathematical ability for grades IV and V students.
- There was no statistically significant difference in cognitive ability of students of grades IV and V.

Following hypotheses were rejected on the basis of total sample data

- There was no statistically significant difference in mathematical ability for female and male students.
- There was no statistically significant difference in cognitive ability for female and male students.
- There was no statistically significant difference in mathematical ability for private and public students.
- There was no statistically significant difference in cognitive ability for private and public students.
- There was no statistically significant difference in mathematical ability for different grades
- There was no statistically significant difference in cognitive ability for different grades.

These results are similar to those of the studies discussed in the review of literature (for example, Nyborg, 2015; Bryden, 1995; DeLay, Laursen, Kiuru, Poikkeus, Aunola, & Nurmi, 2015). But this study found that the importance in grades show varying patterns in even steadiness.

Conclusion

The main conclusion of the study is that difference exists in mathematical and cognitive ability with reference to gender, sector and grade. This conclusion has important implications for the teaching of mathematics in Pakistani elementary classes. Teachers can use such teaching strategies and materials that can exploit this possibility of changing ability for the success of elementary students in mathematics. But to get practical benefits of this theoretical possibilities it is essential that teachers discard the intuition based beliefs and strategies. Though there are weaknesses in the design of the study as only test scores are used as data, and sample was selected by convince sampling, the study is important for its implications for teaching practices traditionally used to teach mathematics in Pakistan.

Recommendations

The study can put forward the following recommendation to bring its implication in the classroom:

a. Teacher should use wide range of techniques and material for teaching mathematics to male and female students to cater for difference in abilities.
b. The teachers of different grades should be share with one another their experiences and data about students' performance in previous grades. This would help to assess the abilities of students and align teaching with these abilities.

c. Teachers of different sectors (public and private) should be called upon to share their experiences with one another in the conferences, workshops and action research reports.

References

Busato, V. V., Prins, F. J., Elshout, J. J., & Hamaker, C. (2000). Intellectual ability, learning style, personality, achievement motivation and academic success of psychology students in higher education. *Personality and Individual differences*, *29*(6), 1057-1068.

Dede, C. (2008). Theoretical perspectives influencing the use of information technology in teaching and learning. In *International handbook of information technology in primary and secondary education* (pp. 43-62). Springer US.

DeLay, D., Laursen, B., Kiuru, N., Poikkeus, A. M., Aunola, K., &Nurmi, J. E. (2015). Stable same-sex friendships with higher achieving partners promote mathematical reasoning in lower achieving primary school children. *British Journal of Developmental Psychology*, *33*(4), 519-532.

Dreyfus, T. (2002). Advanced mathematical thinking processes. In *Advanced mathematical thinking* (pp. 25-41). Springer Netherlands.

Eagly, A. H., & Mitchell, A. A. (2004). Implications for the Sociopolitical Attitudes of Women and Men. *Praeger guide to the psychology of gender*, 183.

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological bulletin*, *136*(1), 103.

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and math. *Science-New York then Washington-*, *320*(5880), 1164.

Halpern, D. F., & LaMay, M. L. (2000). The smarter sex: A critical review of sex differences in intelligence. *Educational Psychology Review*, *12*(2), 229-246.

Hill, C., Corbett, C., & St Rose, A. (2010). *Why so few? Women in Science, Technology, Engineering, and Mathematics*. American Association of University Women. 1111 Sixteenth Street NW, Washington, DC 20036.

Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, *40*(1), 281-310.

Krutetskii, V. A. (1976). The psychology of mathematical abilities in school children. Chicago: University of Chicago Press.

Matsumoto, D. R. (Ed.). (2009). *The Cambridge dictionary of psychology* (Vol. 114). Cambridge: Cambridge University Press.

Miller, D. I., & Halpern, D. F. (2014). The new science of cognitive sex differences. *Trends in cognitive sciences*, *18*(1), 37-45.

Nyborg, H. (2015). Sex differences across different racial ability levels: Theories of origin and societal consequences. *Intelligence*, *52*, 44-62.

Reilly, D., Neumann, D. L., & Andrews, G. (2016). Sex and sex-role differences in specific cognitive abilities. *Intelligence*, *54*, 147-158.

Resnick, L. B. (1987). The 1987 presidential address learning in school and out. *Educational researcher*, *16*(9), 13-54.

Vilkomir, T., & O'Donoghue, J. (2009). Using components of mathematical ability for initial development and identification of mathematically promising students. *International Journal of Mathematical Education in Science and Technology*, 40(2), 183-199.