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Non Cognitive and Cognitive predictors of Mathematics achievement & its improvement in 5th-8th graded students

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Abstract

Purpose of the current study is to investigate simple and multiple relations between achievement motivation, fluid intelligence and working memory with mathematics achievement. The Statistical population involved the entire 5th-8th graded students studying in Durgapur K.C. high school in south 24 parganas in 2019. From these, two hundred late childhood students (10-13 yrs) were selected as sample through stratified random sampling method. For gathering data, the following instrument is used. Muthee achievement motivation inventory, Raven's Standard Progressive matrices, Working Memory Index (WISC-IV) - Digit Span and Letter-Number Sequencing, and students' mathematics score in exam throughout 2019 academic session. Correlation method was the research method. For data analysis, Pearson's product moment correlation (r), ANOVA and Multiple Regressions have been used by SPSS. The Results showed that all of the variables correlate with together significantly. Achievement motivation, fluid intelligence and working memory were predicator of mathematics achievement statistically significant.

Key words: Achievement Motivation, Fluid Intelligence, Mathematics Achievement, Working Memory.

Introduction

Mathematics is one of the essential tools of everyday life. The acquisition of mathematical abilities is not only one of the foundation stones of the schooling process, but it also affects society in general ([20]Gross et al., 2009). Mathematics is a universal subject, so much a part of life that anyone who is a participating member of society must know basic mathematics. Students' mathematical achievement, however, is ultimately determined and limited by the opportunities they have had to learn. "All students must learn to think mathematically, and they must think mathematically to learn" ([30]Kilpatrick, Swafford, and Findell, 2001). Mathematics is the foundation of all science and engineering disciplines, and all scientific methodologies. According to [44]Hembree (1990) reported that when students avoid the study of mathematics, it erodes the country's resources base in science and technology, since it is a base for science and technological fields, another side of non-technical fields such as education, business, social and behavioral sciences, humanities and the arts mathematical skills are also needed. So it is essential in this competitive, rapidly changing environment, to strengthen students' mathematics achievement in schools.

In south 24 parganas, there is very poor performance in Mathematics in most of the public schools. It is observed that many students are able to achieve good grades in all other subjects but they fail or perform not up to the mark in Mathematics. These students are seen to show symptoms like low motivation and attitude and high mathematics anxiety. Therefore, understanding the factors that have a decisive influence on children's performance in mathematics is of major relevance from an educational point of view. To know the root cause of failure in Mathematics performance, teachers, parents, stakeholders should know about predictors of Mathematics achievement.

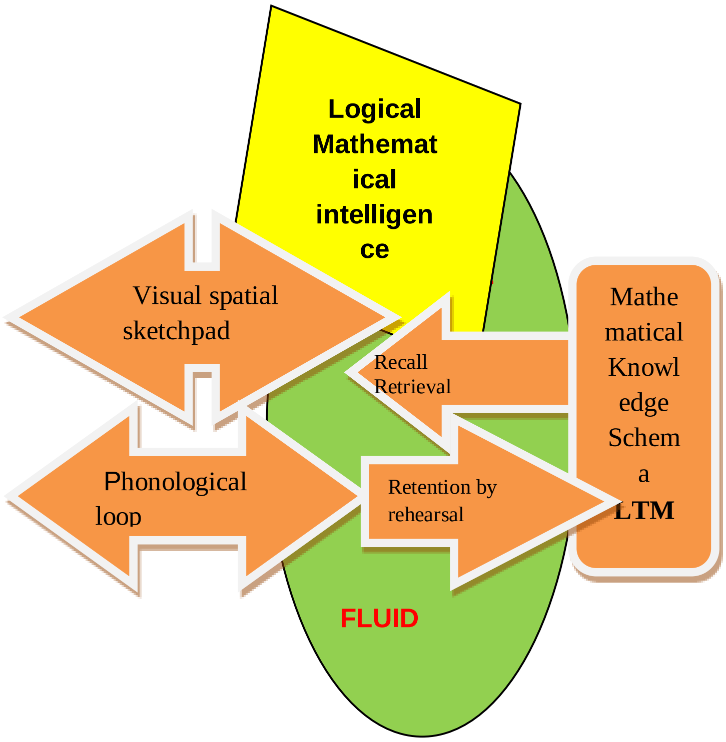
High or low mathematics performance depends on some non-cognitive factors like mathematics attitude and achievement motivation. Mathematics attitude should be viewed as a predisposition to respond in an unfavourable or favourable way to mathematics. By accepting this view, mathematics attitude includes relevant beliefs, behavior and attitudinal or emotional reactions. Researches indicated that, there is a positive relation between mathematics attitude and mathematics achievement ([34]Ma, & Kishor, 1997a; [45]Saha, 2007; [49]Thomas, 2006). Researches reviled that some variables mediated the effect of math attitude and mathematics achievement ([26]Kabiri, & Kiamanesh's, 2004; [28]Kiamanesh, Hejazi, & Esfahani, 2004). Some of these variables are intelligence quotient ([5]Blair, Gamson, Thorne, & Baker, 2005; [6]Bull & Scerif, 2001, [14]Evans, Floyd, McGrew, & Leforgee, 2002; [19]Grissmer, 2000) and motivation for mathematics ([29]Khoush Bakht, and Kayyer, 2005; [36]Md. Yunus, & Wan Ali, 2009). Motivation refers to "a student's willingness, need, desire and compulsion to participate in, and be successful in the learning process" ([36]Md. Yunus, Wan Ali, 2009). According to findings of [29]Khoush Bakht, and Kayyer, (2005), [36]Md. Yunus, and Wan Ali (2009), [37]Middleton, and Spanias (1999) there is significant positive relation between motivation and students' mathematics achievement. Two motives are directly involved in the mathematics performance, implicit and explicit. Implicit motives are spontaneous impulses to act, also known as task performances, and are aroused through incentives inherent to the mathematics task. Explicit motives are expressed through deliberate choices and more often stimulated for extrinsic reasons. There are many students who are highly motivated and do anything their teacher asks. However, the number of poorly motivated students is substantial and seems to be growing. In high schools, these students tend to be clustered in beginning level classes because their lack of effort keeps them from gaining the skills needed to take more advanced mathematics.

Studies of cognitive development have focused on processing speed (PS), working memory (WM) capacity, and fluid reasoning (FR) as three inter-related cognitive abilities that develop markedly from childhood through adulthood and that predict individual differences in mathematics performance ([8]Cowan et al., 2005). Studies from late childhood through young adulthood indicate that gains in PS support gains in WM capacity that, in turn, supports FR ([9]Coyle, Pillow, Snyder, & Kochunov, 2011; [15]Fry & Hale, 1996; [27]Kail, 2007).

Previous studies claim that mathematical abilities are mainly related to working memory ([41]Passolunghi et al.,2007; [23]Holmes et al.,2009; [1]Alloway and Alloway, 2010; [47]Swanson, 2011), and training in WM skills seems to have beneficial effects on some mathematical abilities ([31]Klingberg, 2010).
Baddeley's multi-component model of working memory ([3]Baddeley and Logie, 1999):
"1. The temporary retention of relevant mathematics information, either in a 'visual–spatial sketchpad' (for visual spatial information) or a 'phonological loop' (for retaining verbal information). 2. The manipulation of relevant ideas to form new knowledge using the appropriate cognitive activity in a 'central executive'. 3. The retrieval of aspects of the person's existing knowledge, used as a foundation for interpreting the teaching information and for building new knowledge." A key function of the central executive subcomponent of working memory is the accessing and retrieving of knowledge from long-term memory ([2]Andersson, 2007).
Individuals with high working memory capacity performed better than individuals with low working memory capacity as the difficulty of math problems increased ([40]Osei-Boadi, Brenda, 2016). It has been established that working memory deficit is considered as the key cause of mathematics learning difficulties. Studies have shown that WM is plastic and thus can be improved through training. According to the findings of [46]St. Clair-Thompson (2010) as cited in [39]Morrison & Chein (2011) Working memory functioning improves throughout childhood, adolescence, and adulthood and can be strengthened through intensive practice and training. Working memory strategy training in adolescents would lead to improvements in mental calculation. [50]Zhao et.al (2017) find that a modulatory role of achievement motivation on working memory (WM) training benefits. The high achievement motivation students displayed a larger training gain than the low achievement motivation students.
Participants who score higher on working memory tasks demonstrate an increased ability to control their attention while maintaining their task goals in the presence of interference, and this ability is strongly correlated with general intelligence (g) ([7]Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; [13]Engle,

Tuholski, Laughlin, & Conway, 1999; [22]Heitz, Unsworth, & Engle, 2004)

Fluid intelligence (*Gf*) that has been found to be especially closely related to general intelligence (g) ([32]Kvist & Gustafsson, 2008; [35]McArdle & Woodcock, 1998) has frequently played a leading role in studies on the relationship with mathematics performance. [33]Lohman (2001) argues that *g* is largely synonymous with fluid intelligence (*Gf*), which is considered to be one of the most important factors in novel mathematics learning and comprises those sets of abilities associated with abstract reasoning, inductive & logical reasoning, analogical reasoning and higher-order thinking. Fluid Reasoning supports mathematical thinking and reasoning throughout the school years.FR is the best predictor of future math achievement ([18]Green et al, 2018). Previous research suggesting that fluid intelligence can be improved with cognitive training on working memory ([42]Peng et.al 2017, [24]Jaeggi et.al 2008).Fluid Intelligence has always been thought to have a strong hereditary component, immutable even with training, but the new research shows that training in continuous performance tasks (dual *n*-back tasks) stimulates brain activity leading to improved results as reflected through intelligence tests. The training effect is dosage-dependent i.e. the more training, the more improvement in *Gf* ([24]Jaeggi, Buschkuehl, Jonides, and Perrig, 2008).
[33]Lohman (2001) reviews evidence that a central working memory system underlies inductive reasoning ability and thus a general inductive reasoning ability that cuts across all of the intelligences. According to [16]Gray et al., (2003) by improving working memory fluid intelligence can also be improved as these two abilities share neural networks in the prefrontal and parietal cortices. There is also neurological evidence for substantial overlap between the processes evoked by measures of *g* and the processes evoked by measure of working memory: Both tasks tend to activate the lateral prefrontal cortex (PFC) as well as left and right parietal regions ([12]Duncan & Owen, 2000; [16]Gray, Chabris, & Braver, 2003; [17]Gray & Thompson, 2004).



One of students' characteristics which play an important role in learning mathematics is logical-mathematical intelligence ([11]Arum, Kusmayadi & pramudya, 2018). There is a positive correlation between logical-mathematical intelligence and mathematical problem solving ([43]Rahbarnia, et al.2014). However, there are a few studies that pay attention to students' logical-mathematical intelligence profiles generally and specifically on each indicator. Besides this, there is a significant relationship between spatial ability and achievement in mathematics ([4]Battista, 1990), positive relationship between visual imagery, spatial ability and mathematical problem solving ([21]Hegarty, Kozhevnikov 1999).

Significance of study

It is observed that there are 5th -8th graded school students who get good marks in other subjects but their score on achievement test in mathematics is low. The present study is a boon to students, teachers, parents and stake holders as it is possibly be able to relate fluid intelligence, working memory along with achievement motivation in mathematics achievement because of those are predicts future mathematics among children and adolescents

Review of literature

[25]**Middleton and Others (1999)** studied "Motivation for Achievement in Mathematics: Findings, Generalizations, and Criticisms of the Research" Researchers interested in studying motivation in the content domain of school mathematics need to examine the relationship that exists between mathematics as a socially constructed field and students' desire to achieve. First, findings across theoretical orientations indicate that students' perceptions of success in mathematics are highly influential in forming their motivational attitudes. Second, motivations toward mathematics are developed early, are highly stable over time, and are influenced greatly by teacher actions and attitudes. Third, providing opportunities for students to develop intrinsic motivation in mathematics is generally superior to providing extrinsic incentives for achievement. Fourth, inequities exist in the ways in which some groups of students in mathematics classes have been taught to view mathematics. Last, and most important, achievement motivation in mathematics, though stable, can be affected through careful instructional design.

[38]**Moenikia and others** (**2010**) studied "A study of simple and multiple relations between mathematics attitude, academic motivation and intelligence quotient with mathematics achievement." The Results showed that all of the variables correlate with together significantly. The shares of mathematics' attitude, academic motivation and intelligence quotient were .362, .030, and .360, respectively in predicting of math achievement. It is should be mentioned that the share of academic motivation in this prediction in the presence of two other variable is not significant.

[49]**Tzoneva.I (2015)** published a paper titled as "The Relations between Working Memory and Mathematics Achievement of Children in the Primary Grades". The research is underpinned by Baddeley's model of working memory and places particular emphasis on the roles of the central executive and the phonological loop components of the working memory system. The finding is that the executive working memory system available to young children at school entry is predictive of later performance of measures of mathematics achievement.

[18]**Green and others (2017)** published a paper titled as "Fluid reasoning predicts future mathematics among children and adolescents." They interpret that FR is a foundational skill that influences future development of numerical reasoning and potentiates math problem solving skills. These results support and extend Cattell's (1971; 1987) notion that FR development is an important cognitive precursor for even the most basic math skill development, including timed arithmetic, as well as more complex equations and word problems.

The gaps identified

In previous study, the investigation was done for single predictor of mathematics performance. The current study was integrated study which includes some possible predictor.

Purpose of the present study

The main purpose was to determine the role of non cognitive predictors (viz. Achievement Motivation, Mathematics Attitude) and cognitive predictors (viz. fluid intelligence, working memory) on Mathematic achievement and to investigate to find out the way of enhancing of those predictors in 5^{th} -8^{th} graded school students whose cognitive function are still developing. So specifically the objectives can be stated as under:

I. To study the relation between achievement motivation and mathematics achievement among 5^{th} - 8^{th} graded school students.

II. To study the relation between fluid intelligence and mathematics achievement among 5^{th} -8^{th} graded school students.

III. To study the relation between working memory and mathematics achievement among 5^{th} -8^{th} graded school students

IV. The predictors of mathematics achievement include:
   a. Achievement Motivation
   b. Fluid intelligence
   c. Working memory

Hypotheses

H_0 -1: There is no significant relationship between achievement motivation and mathematics achievement among 5^{th} -8^{th} graded school students.

H_0 -2: There is no significant relationship between fluid intelligence and mathematics achievement among 5^{th} -8^{th} graded school students.

H_0 -3: There is no significant relationship between working memory and mathematics achievement among 5^{th} -8^{th} graded school students.

H_0 -4: There is no significant multiple correlation and prediction of mathematics achievement with achievement motivation, fluid intelligence, working memory.

Variables

In this study the variables are –
i) Independent- Achievement Motivation, Fluid intelligence, Working Memory.
ii) Dependent- mathematic achievement
iii) Controlled- age (10-13 yr)

Population and sample

The 5^{th}-8^{th} graded students studying in Durgapur K.C. high school in south 24 parganas constitute the population. Two hundred late childhood students (10-13 yrs) were selected as sample through stratified random sampling method.

Tools & Statistical analysis

Muthee achievement motivation inventory, Raven's Standard Progressive matrices, Working Memory Index (WISC-IV) - Digit Span and Letter-Number Sequencing, and students' mathematics score in mathematics exam throughout academic session 2019.
For data analysis, Pearson's product moment correlation (r), ANOVA, Multiple Regressions, path analysis method was used by SPSS.

Table -1: Pearson's correlations coefficient, Mean and Standard deviation-

	Mathematics Achievement	Achievement Motivation	Fluid Intelligence	Working Memory	Mean	Std. Deviation
Mathematics Achievement	1.00					
Achievement Motivation	.493*	1.00				
Fluid Intelligence	.658*	.297*	1.00			
Working Memory	.643*	.366*	.568*	1.00		
N= 200 *- 0.01 level of significance						

Results from Table 1, indicated that there are positive and significant simple correlation between achievement motivation, fluid intelligence and working memory with mathematics achievement .493, .658 and .643 respectively. Also Table 1 showed that there is a positive and significant correlation between fluid intelligence and achievement motivation ($r = .297$, $P < .01$); working memory and achievement motivation ($r = .366$, $P < .01$); working memory and fluid intelligence ($r = .568$, $P < .01$).

In order to determine the influential achievement motivation, fluid intelligence and

working memory in predicting the mathematics achievement, taking the advantages of the enter method, multiple regression analysis was used.
As it can be seen from the results of table 2, adjusted R square is .606 and F =75.924 is significant (p < .01). So, achievement motivation, fluid intelligence and working memory may predict mathematics achievement. From among these, the shares of achievement motivation, fluid intelligence and working memory were .249, .399 and .330, respectively in predicting of mathematics achievement.

Table- 2. Predicting the mathematics achievement on the base of achievement motivation, fluid intelligence and working memory:
Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.779[a]	.606	.598	20.327

a. Predictors: (Constant), Achievement Motivation, Fluid Intelligence, Working memory.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	94107.956	3	31369.319	75.924	.000[b]
	Residual	61149.019	148	413.169		
	Total	155256.975	151			

a. Dependent Variable: Mathematics Achievement
b. Predictors: (Constant),Achievement Motivation, Fluid intelligence, Working Memory

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-40.778	6.921		-5.892	.000
	Achievement Motivation	.287	.064	.249	4.465	.000
	Fluid Intelligence	.451	.072	.399	6.230	.000
	Working Memory	1.157	.230	.330	5.039	.000

Dependent Variable: Mathematics Achievement

Interpretation and discussion

Objective-1

Table-1 shows correlation value (R) between Achievement Motivation and Mathematics Achievement is .493. It is significant at 0.01 level. The null hypothesis is rejected.
So there is moderate positive relationship between Achievement Motivation and mathematics achievement among 5th -8th graded school students. The present findings are supported by the finding of Middleton and et al (1999).

Objective-2

Table-1 shows correlation value (R) between Fluid Intelligence and Mathematics Achievement is .658. It is significant at 0.01 level. The alternative hypothesis is accepted. So there is high positive relationship between fluid intelligence and mathematics achievement among 5th -8th graded school students. The present findings are supported by the finding of Green and et al (2017).

Objective-3

Table-1 shows Correlation value (R) between Working Memory and Mathematics Achievement is .643. It is significant at 0.01 level. The null hypothesis is rejected.
So there is relatively high positive relationship between working memory and mathematics achievement among 5th -8th graded school

students. The present findings are supported by the finding of Tzoneva.I (2015).

Objective-4

From table-2, multiple regression analysis revealed that a set of three variables, viz., achievement motivation, fluid intelligence and working memory, jointly could predict academic achievement to a significant extent. The beta coefficients associated with these variables were: achievement motivation .249; fluid intelligence .399; and working memory .330. The multiple R was found to be .779. It is should be mentioned that the share of fluid intelligence or g factors in this prediction in the presence of two other variable is significant.The present findings are supported by the finding of Moenikia and et al (2010).

Educational Implications

Student's achievement motivation can be uplifted by teachers, parents, school & home environment and peer group. Teacher's own locus of control and classroom management motivates the mathematics achievers. Teachers motivate the mathematics learners by token economy, parent's counseling, checking mathematics home work daily, conducting regular class test and telling them biographies of famous mathematicians. Finally, mathematics teacher's teaching style strongly motivates the students through overall updation of the school atmosphere/climate. Modification of mathematics curriculum is also essential for motivation in mathematics learners. Careful instructional design helps them too. Low achievers should be taught mathematics calculation by joyful playing method using math playing card. The teachers must regularly conduct class test among high achievers who are always intrinsically motivated. Beside school climate, moderately favourable home environment also needs to motivate ([10]Dr.Doley, 2018). High motivation acquisition through vicarious social learning from peers which is known as peer effect, in the school or hostel, can also be beneficial. So, proper and effective peer bonding is also necessary for this purpose.

The assessment of fluid intelligence (G*f*) in 5th - 8th graded school students can serve to identify low achievers who are likely to have difficulty-learning maths. They should be given less mathematics tasks for their lower IQ.

This study makes concerned people aware of the fact that improvement in working memory is possible and these help students to improve the grades in mathematics. Mathematics teachers should engage students in core training and strategy training. Students can start very practically by presenting a 2-by-2 grid of numbers for a few seconds, and then asking the class to transcribe it from memory. Over time, they can build to grids of 3-by-3 and even 4-by-4. Increasingly challenging digit span tasks, as they begin to exceed the limits of pure short-term memory, will spur students' development of both meaningful encoding and retrieval structures. With practice, students will begin to develop a high working memory with long attention span. Specific teaching strategies, teaching model, methods, approach should be adopted by teacher for improving WM and G*f* in 5th -8th graded school students. This is made possible by repeating and reviewing, breaking down information or instructions for calculation, practicing mathematics calculation daily without use of calculator, providing memory aids (like math playing card) and visual support in mathematics laboratory, playing computer based visual and auditory memory games in ICT room in the school. Some specific text should be introduced in mathematics curriculum which enhances WM & G*f* of particular 10-13 yr. aged children.

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