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Fluid Intelligence and Working Memory in relation to Mathematics achievement in adolescent students: AStudy

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Abstract

Purpose of current study was to investigate simple relations between fluid intelligence and working memory with mathematics achievement. The Statistical population involved the entire Durgapur K.C. high Schools students in 2018 (N = 1302). From these, two hundred adolescents (13- 16 yrs) were selected as sample by using purposive sampling. For gathering data, the following instrument was used. Raven's Standard Progressive Matrices, Working Memory Index (WISC-IV) - Digit Span and Letter-Number Sequencing, and students' Mathematics score in final exam. Correlation method was the research method. For data analysis, Pearson's product moment correlation method was used. The Results showed that all of the variables correlate with each other significantly. Fluid intelligence and working memory were predicator of mathematics achievement.

Key words: Adolescent, 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 (Gross et al., 2009). 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.

Mathematics is the abstract science of numbers, quantity, and space, as well as their relations. The essences of mathematics are abstraction,quantification; elicit/identify genericabstract entities, manipulating symbols, establishment of axiomatic rules and rules of derivation. The basic methodologies ofmathematics are abstraction and symbolic inferences. The former is a key step of human creation and an inductive leap of thought that elicits the common properties and quantitative relations of real-world entities by symbolic and generic concepts. The latter is a profound approach to rigorous and formal reasoning among complex phenomena and relations.

Krutetskii's (1976) describes mathematical ability as a complex dynamic phenomenon constituted by following abilities:

- the ability to obtain mathematical information (i.e. formalized perception of mathematical material),
- the ability to process mathematical information (i.e. logical thought, generalization of mathematical objects, relations and operations, the ability to curtail the process of mathematical reasoning and flexibility in mental processes),
- retaining mathematical information (i.e. mathematical memory, which is a generalized memory for mathematical relationships, type characteristics and methods of problem-solving) and
- a general synthetic component, described as a "mathematical cast of mind" (Krutetskii 1976).

Cattell (1971) and Horn (1978) have proposed Cattell and Horn's Theory in which they have distinguished two types of intelligence. a. Fluid intelligence, b. Crystallized intelligence. Cognitive Theories of Intelligence are called process-oriented theories. These focuses on intellectual processes; the patterns of thinking and reasoning in people, used to solve problems. These theories consider intelligence as a process which helps to deal with problems and to find out the answers. They are called cognitive theories because of their focus on fundamental cognitive processes. Cattell theorized that fluid intelligence, often thought to depend on native ability rather than education or acculturation, is distinct from crystallized intelligence (acquired knowledge and skills relating to specific information).

Fluid intelligence is the general ability to think abstractly, reason, identify patterns, solve problems, and discern relationships.*Fluid intelligence* is an innate, biologically or genetically determined capacity and not influenced by education or training. This capacity helps the person in learning and problem solving. This is the ability which is useful in understanding and adjusting to strange situations.It is represented by *Gf*.

Fluid intelligence that has been found to be especially closely related to general intelligence (Kvist & Gustafsson, 2008; McArdle & Woodcock, 1998) has frequently played a leading role in studies on the relationship with mathematics performance.

Many studies claim that mathematical abilities are mainly related to working memory (WM; Geary, 1993; Alloway et al., 2005; Passolunghi and Pazzaglia, 2005; Passolunghi et al.,2007; Passolunghi and Cornoldi, 2008; Holmes etal.,2009; Alloway andAlloway,2010; Swanson, 2011), and training in WM skills seems to have beneficial effects on some mathematical abilities (Klingberg, 2010).

WM model of Baddeley (1986, 2000) has three components: *a central executive component*, *a phonological loop*, and a *visuo-spatial sketchpad*. The phonological and visual components are referred to as ‘slave’ systems given that they hold specialized information for short periods of time. Working memory, thus, is a multifaceted function that captures visual, spatial, kinesthetic, and auditory information, directs attention to it, and coordinates processes to deal with its components, nature, and functioning.

Working memory is the ability to maintain and manipulate information temporarily. Despite its limited capacity, with effective materials and efficient strategies, an individual is able to perform complex cognitive tasks. It is the core of high-level cognitive activities and an essential component in the processes of learning, comprehending, reasoning, problem solving and intelligent functioning. It differs from short term memory in certain aspects. Short-term memory is a unitary storage and a passive place, the working memory is a multi-modal, multi-component, and multi-function place where temporary storage takes place before the information is intentionally transferred to long-term memory – if it is not transferred, it escapes. It is an active system that provides the basis for complex cognitive abilities. In working memory, we consciously process selective information; therefore, working memory is linked to *attention control*.

Working memory is the 'mental thinking space' in which students manipulate or act on aspects of their knowledge during mathematics knowledge or while completing mathematics tasks and problems. It is the activity students engage when they interpret teaching information using knowledge they retrieve from long term memory, when they retain and link partial mathematical ideas to synthesize new mathematical knowledge and when they direct their learning and thinking activity to compute or solve mathematical problems.

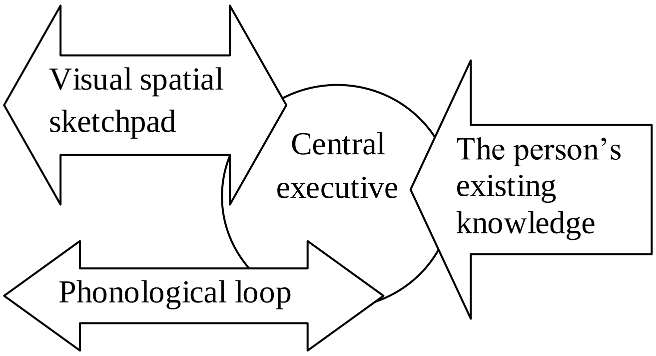
To unpack the role of working memory on learning of mathematics, we may begin with Baddeley's multi-component model of working memory (Baddeley and Logie, 1999). This model identifies various processes:

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.

These components are shown in the following diagram:



The present study aims to examine the relationship in fluid intelligence, WM and mathematical achievement in two hundred samples of adolescent aged13–16 years. This has been chosen mainly because of two reasons. First, Fluid Intelligence develops fully in adolescent aged13–16 years.Some studies suggest that fluid intelligence declines after early adulthood. Second, it is around this age that adolescent already starting to engage in phonological rehearsal Also, there is an increase in the verbal abilities of adolescent that allows them to make a wider use of verbal information. This in turn reflects on an increasing ability to solve mathematical problems with long and complex verbal instructions.

Review of related literature

Primi.R., Ferrão.M.E., Almeida.L.S. (2010) published a paper titled as“Fluid intelligence as a predictor of learning: A longitudinal multilevel approach applied to math”. The association between fluid intelligence and inter-individual differences was investigated using multilevel growth curve modeling applied to data measuring intra-individual improvement on math achievement tests. The general cognitive factor was significantly associated with the parameters of initial level (intercept) and rate of change (slope). A high level of intelligence was associated with higher initial scores, as well as a steeper rise in math scores across the two years.

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.

Andersson.U. (2006)published a paper titled as **“**The contribution of working memory to children's mathematical word problem solving”. The findings demonstrate that the phonological loop and a number of central executive functions (shifting, co-ordination of concurrent processing and storage of information, accessing information from long-term memory) contribute to mathematical problem solving in children.

Weijer-Bergsma and others (2014) studied “Verbal and visual-spatial working memory and mathematical ability in different domains throughout primary school.” The results showed that as grade level progressed, the predictive value of visual-spatial working memory for individual differences in level of mathematics performance waned, while the predictive value of verbal working memory increased.

Tzoneva.I (2015) published a paper titled as“The Relations between Working Memory andMathematics Achievement of Children in the Primary Grades”. The research is underpinned by Baddeley’s model of working memory (Baddeley & Hitch, 1974; Baddeley, 1986, 1996, 2000) 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.

Brenda and others (2016)studied “The Role of Working Memory Capacity in Math Performance.” They found that high working memory capacity individuals took less time to solve the math problems than low working memory capacity individuals. The finding indicates that when problems were relatively easy (i.e., nocarry required), participants with low and high working memory capacity performedequally well. When the task complexity increases (i.e. theproblems get more difficult) individuals with high working memory capacity are betterequipped to handle such challenges because they have more cognitive resources to drawon.

Alloway and others (2017) studied “The relationship between working memory, IQ, and mathematical skills in children.”A different pattern emerged that was dependent on both the memory task and the math skill. The pattern of findings provides contributions of working memory and vocabulary to different mathematical skills.

Jaeggi *et al*. (2008) published a paper titled as “Improving fluid intelligence with training on working memory.” They demonstrate that the extent of gain in intelligence critically depends on the amount of training: the more training, the more improvement in *Gf*. That is, the training effect is dosage-dependent.

Unsworth and others (2014) published a paper titled as “Working memory and fluid intelligence: Capacity, attention control, and secondary memory retrieval.”The results demonstrated that capacity, attention control, and secondary memory were uniquely related to WM storage, WM processing, and *Gf*. These results are consistent with the multifaceted view of WM, suggesting that individual differences in capacity, attention control, and secondary memory jointly account for individual differences in WM and its relation with *Gf*.

Colom and others (2015) studied “Fluid intelligence and working memory capacity: Is the time for working on intelligence problems relevant for explaining their large relationship?”The present report analyzes a group of three hundred and two participants that completed a set of three fluid tests and six working memory tasks. Latent variable analyses revealed consistent correlations (weighted average $r = .86$) between fluid ability and working memory capacity irrespective of administration times.

Zelechowska and others (2017)did a Study entitled “Working Memory Training for School children Improves Working Memory, with No Transfer Effects on Intelligence.” Their study implies that working memory training for school children improved their working memory capacity, as measured with independent tasks. However, such training did not improve general fluid or crystallized intelligence.

Peng and others (2017) studied “The effects of working memory training on improving fluid intelligence of children during early childhood.” Results indicated that, the experimental group significantly enhanced their working memory performance. The experimental group also significantly outperformed the two control groups on the fluid intelligence post test and maintained their superior performance for up to 12 months.

Significance of study:

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 shame, guilt, and depression and develop other psychological problems like blaming the teacher or using other defenses for their failure. In the long run their chances of admission to good college or institution also fade.

The present study is a boon to these students, teachers, parents and stake holders as it is possible to relate fluid intelligence along with working memory in mathematic achievement in adolescents.

The assessment of fluid intelligence (**G*f***) in adolescents can serve to identify those who are likely to have difficulty-learning maths. This study help and guide teachers to better understand which interventions may be most fruitful for individual students at different developmental levels of ***Gf*** and math achievement skills.

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 St. Clair-Thompson(2010) as cited in 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. According toGray 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.

This study will help the teachers and the parents to help the weak students in mathematics; as the upcoming theories have highlighted that those who are low in their mathematical grades can be helped to improve by improving their fluid intelligence and working memory.

Objectives

- To study the relation between fluid intelligence and mathematics achievement among adolescent students.
- To study the relation between working memory and mathematics achievement among adolescent students.
- To study the relation between fluid intelligence and working memory among adolescent students.

Hypotheses

H_0 -1: There is no significant relationship betweenfluid intelligence and mathematics achievement among adolescent students.

H_0 -2: There is no significant relationship betweenworking memory and mathematics achievement among adolescent students.

H_0 -3: There is no significant relationship betweenfluid intelligence and working memory among adolescent students.

Research Design

The correlational design is used in this study.

Variables

In this study the variables are –
i) Independent-fluid intelligence, working memory ii) dependent- mathematic achievementiii) Controlled- age (13-16 yr)

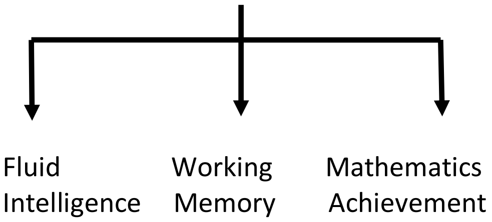
Population

In the present study the students studying in Durgapur K.C. high school in 2018 constitute the population (N = 1302).

Sample

Two hundred adolescents (13- 16 yrs) were selected as sample through purposive sampling method.

Adolescent
(Age: 13 to16 yrs) ,
N=200



Tools

For gathering data, the following tools were used. Raven's Standard Progressive Matrices (Reliability ·82-1·00 & validity ·85), Working Memory Index (WISC-IV) - Digit Span and Letter-Number Sequencing (Reliability ·79 - ·92), and students' mathematics score in final exam.

Procedure

The students were clearly explained about the aims and objectives of the study and then after getting their consent to participate they were administered two (Raven's SPM & WISC-iv) tests individually till the desired number of student's data was obtained.

Statistical analysis

For data analysis, Pearson's product moment correlation method was used by SPSS.

Result

Appendix

From table-1, it is evident that mean of Mathematics Achievement is 29.44 and standard deviation is 12.80098, mean of Fluid Intelligence is 28.25 and standard deviation is 26.92353& mean of Working Memory is 5.432 and standard deviation is 11.81749.

From table-1, it is shown that Correlation value (R) between Fluid Intelligence and Mathematics Achievement, between Working Memory and Mathematics Achievement & between Fluid Intelligence and Working Memory are 0.545, 0.620, and 0.461 respectively.

Interpretation and discussion

Objective-1

Table-1 shows correlation value (R) between Fluid Intelligence and Mathematics Achievement are 0.545. It is significant at 0.01 level. The null hypothesis is rejected.

So there is moderate positive significant relationship betweenfluid intelligence and mathematics achievement in adolescent students. The present findings are supported by the finding of Moenikia and et al (2010) Primi.R. and et al (2010).

Objective-2

Table-1 shows Correlation value (R) between Working Memory and Mathematics Achievement are 0.620. It is significant at 0.01 level. The null hypothesis is rejected.

So there is moderate positive significant relationship betweenworking memory and mathematics achievement in adolescent students. The present findings are supported by the finding of Tzoneva.I (2015),Alloway and et al (2017).

Objective-3

Table-1 shows correlation value (R) between Fluid Intelligence and Working Memory are 0.461. It is significant at 0.01 level. The null hypothesis is rejected.

So there is positive significant relationship betweenfluid intelligence and working memory in adolescent students. The present findings are supported by the finding of Unsworth and et al(2014),Colom and et al (2015).

Conclusion

The Results showed that all of the variables correlate with each other significantly. Fluid intelligence and working memory were predicator of mathematics achievement statistically significant.

Limitation of the study

- The present study is based on a comparatively smaller number of school students (N=200) so generalization of the findings is not possible.
- Randomization has not been used in choosing the samples.
- It is a cross sectional study, it would be better to conduct a longitudinal study.
- The study is conducted only in rural area and not representative all of the students of South 24 parganas.
- The study is conducted only in Bengali medium school.

Suggestion for future work

- Larger sample would help in generalization of the research findings.
- Randomized sample would be representative of the population under study.
- A longitudinal study is desirable for obtaining more reliable and detailed results.
- The present study is conducted only in Bengali medium school students. It can be expanded to all English, Hindi and Bengali medium Private and Government school students of different rural and urban areas of South 24 parganas.
- Gender differences can also be studied in further researches.
- Different components of workingmemorycan be included in further research.

EducationalImplications

It is observed that there are adolescents 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 along with working memory in mathematics achievement of the students.

The assessment of fluid intelligence (**G*f***) in secondary school can serve to identify students who are likely to have difficulty-learning maths. This study is help and guide teachers to better understand which interventions may be most fruitful for individual students at different developmental levels of **G*f*** and math achievement skills.

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 and also on an average achievement. This is made possible by repeating and reviewing, breaking down information or instructions, providing memory aids and visual support, playing visual and auditory memory games. Apart from this computer based support is also be given to the student's like Cogmed and Dybuster Calcularis which are designed to improve skills in maths using WM, improving attention, behaviour and capacity to learn. Dybuster Calcularis is mathematical leaning software which lays solid foundation for mathematics especially in early age. (Klingberg et al., 2005; Holmes et al., 2009).

Specific teaching strategies, teaching model, methods, approach should be adopted by teacher for improving WM and G*f* in adolescents. The researcher offers three basic recommendations to teacher who teaches in the classroom.

First, mathematics teachers should engage students in tasks that seek to build working memory itself through two broad approaches i.e. core training and strategy training. Core training involves demanding working memory tasks intended to enhance domain-general working memory mechanisms, while strategy training promotes the use of domain-specific strategies, including encoding and retrieval, to support the retention of information over time.

Second, the teaching of problem solving strategies and techniques should incorporate an increased focus on hands-free mathematics like without use of calculator.

Third and finally, teachers should encourage in their students the pursuit of skilled memory. Digit memorization need not be confined to Pi Day; they 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 skilled memory, and to reap the cognitive and educational rewards.

Some specific text should be introduced in mathematics curriculumwhich enhance WM & G*f* of particular 13-16 yr. aged adolescents.

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Appendix

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

	Mathematics Achievement	Fluid Intelligence	Working Memory	Mean	Std. Deviation
Mathematics Achievement	1.00			29.440	12.80098
Fluid Intelligence	0.545**	1.00		28.25	26.92353
Working Memory	0.620**	0.461**	1.00	5.432	11.81749
N= 200 **- 0.01 level of significance					