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Multiple Intelligences as Predictors of Mathematics Achievement

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This paper explores the association between the multiple intelligence types and the performance in mathematics of 1,000 secondary school students from the district of Guntur, Andhra Pradesh, India. Using correlational and regression analyses, we analysed the predictive power of Gardner's nine intelligence dimensions (linguistic, logical-mathematical, bodily-kinesthetic, spatial, musical, naturalistic, interpersonal, intrapersonal, and existential) on mathematics performance. There was a significant positive correlation between the multiple intelligence and the mathematics achievement ($r=0.240$, $p<0.01$). The association was significant in the $\chi 2$ analysis ($\chi^2=14.06$, $p<0.01$). A stepwise regression analysis indicated that composite of intelligence dimensions accounted for 83.35% of the variance in mathematics achievement ($R^2= 0.8335$) and the strongest predictors were logical-mathematical intelligence (($\beta=0.459$, $p<0.01$), intrapersonal intelligence ($\beta=0.295$, $p<0.01$), and spatial intelligence (($\beta=0.270$, $p<0.01$). The findings support Gardner's multiple intelligence theory and the implication that mathematical achievement is influenced by different cognitive factors other than the traditional ones. Implications for `differentiated instruction', curriculum and assessment are discussed.

Keywords: multiple intelligence, mathematics achievement, gardner's theory, regression analysis, secondary education, predictive modeling

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1. Introduction

The relationship between intelligence and scholastic achievement has been a matter of concern for scientists and educators for more than 100 years. From a traditional psychometric perspective, general intelligence (g factor) is the best predictor of school success, but Gardner's (1983) multiple intelligences theory questioned this single dimension conception of intelligence and proposed that human cognitive abilities are comprised of a number of relatively distinct intellectual capacities. Gardner identified eight different intelligences (linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic), which he later claimed a ninth dimension, existential intelligence.

Mathematics achievement is a pivotal educational outcome, opening the doors to higher levels of academic and professional pursuits. Once thought to relate only to logical-mathematical intelligence, emerging evidence is pointing towards the involvement of multiple intelligence facets in the acquisition of mathematical skills. Spatial intelligence enables us to perform geometric thinking and to visualize (Hidayah, 2015), linguistic intelligence is related to understanding word problem (Khan, 2018), and intrapersonal intelligence assists metacognitive control in solving a problem (Armstrong, 2009).

Although there are theoretical arguments for the involvement of different types of intelligence in mathematics learning, the empirical results are inconsistent. Some have found significant correlations between certain aspects of intelligence and achievement in mathematics (Sreeraj, 2015; Vadivukarasi, 2022), others have found none or too weak ones (Filiz, 2010). In addition, some of the previous studies used a bivariate analysis approach to examine the relationships without controlling for the intercorrelations among the different types of intelligence, thus limiting the understanding of the unique effects of each type of intelligence.

The current study fills these gaps by means of a series of correlational and regression analyses to investigate (1) the general relation between multiple intelligence and mathematics achievement, (2) the profile of relations at the level of intelligence by levels of achievement, and (3) the relative predictive contribution of each intelligence dimension to mathematics achievement after partialling out the effects of the others. Knowledge of these relations could be used to help inform differentiation instruction, curriculum design, and assessment in mathematics education.

2. Theoretical Framework

2.1 Gardner's Multiple Intelligence Theory

Gardner’s (1983, 2011) notion of multiple intelligences developed as a result of neuropsychological studies of brain-damaged individuals, researches on prodigies and outstanding people, and cross-cultural comparisons of cognitive functioning. Contrary to traditional intelligence theories based on psychometric g-factor, in Gardner’s model intelligence is viewed as multiple, relatively independent domains with own distinct developmental pathways, neural mechanisms and symbolic systems.

8 criteria for a type of ability to count as a separate intelligence include: it can be isolated by brain damage; it manifests in exceptional individuals; it possesses identifiable core operations; it has a distinctive developmental course; it is evolutionarily entire plausible; it is supported by experimental psychology; it has support from psychometric studies, and it can be expressed in symbolic encoding. Based on this demanding criterion, he identified nine forms of intelligences:

1. Linguistic intelligence: Sensitivity to the sounds, rhythms, and meanings of spoken language, and of the written language.
2. Logical-mathematical intelligence: Capacity to think logically and reasonably about problems, to carry out mathematical operations, and to inquire of matters experimentally.
3. Spatial intelligence: The recognition and manipulation of patterns in a large and a small scale space.
4. Body-Kinesthetic Intelligence: The ability to use one body or part of one’s body to solve a problem or make a product.
5. Musical intelligence: the capacity to perform, compose, and enjoy musical patterns.
6. Emotional and Social Intelligence: Development of the social mind to interpret others’ goals, wishes and needs and to cooperate with them.

7. Intrapersonal intelligence: The ability to understand oneself, one's desires, one's fears and one's potentials and to uses such understanding.
8. Naturalistic Intelligence: The ability to distinguish and categorize plants, animals and minerals – involving Taxis.
9. Existential intelligence: The capacity to think about ultimate issues of existence, life, death, and consciousness.

2.2 Multiple Intelligence and Mathematics Learning

Logical-mathematical intelligence is certainly the most relevant intelligence for mathematics but current research claims that learning mathematics involves many dimensions of intelligence. Spatial intelligence is the ability to reason about spatial relations and is used for geometric reasoning, mental visualization of mathematics concepts, and mental image processing (Gul et al., 2020). Linguistic intelligence is required for understanding word problems, mathematical language, and transcripts of abstract symbolic notations (Agarwal & Pal, 2018). Metacognitive processes which are essential in solving mathematical problems, such as planning, monitoring, and evaluating of solution methods, are also enabled by Intrapersonal intelligence. Group learning, mathematical dialogue, and peer learning (Interpersonal Intelligence) Interpersonal intelligence is the ability to understand, communicate and engage with others (Khan, 2018). Even apparently unrelated intelligences, such as musical intelligence, might in fact play a role, for instance when we consider the patterns and rhythms that underlie mathematical sequences and functions.

Besides being theoretically sound, the empirical evidence for the engagement of multiple intelligences in math learning is not unequivocal. Some investigations reveal considerable positive correlations between different dimensions of intelligence and mathematics achievement (Chittaranjan Nayak, 2002; Sreeraj, 2015), While other studies suggest weak or no relationships (Murray, 2016). These discrepancies might represent differences in method, sample attributes, or genuine/contextual differences in how intelligences and mathematics learning associate.

3. Methodology

3.1 Research Design

The study used a quantitative correlational design to investigate the associations among the multiple intelligence domains and mathematics achievement. The method permitted study of naturally occurring relationships in the absence of experimental intervention.

3.2 Participants

The participant of the present study includes 1000 students of class IX (500 boys and 500 girls) of 25 secondary schools in the guntur district of Andhra Pradesh, India selected through stratified random sampling. Mean age of participants - 14.2 years (SD=0.6). The sample was drawn from a range of rural and urban areas, public and private schools, and instruction in Telugu and English.

3.3 Instruments

Multiple Intelligence Scale (MIS): The MI Scale by Agarwal and Pal (2018) was used. The scale has 90 items (10 items for each dimension of intelligence) with a 5-point likert scale (Always=5, Mostly=4, Often=3, Rarely=2, Never=1). Reliability coefficients ranged between 0.71 and 0.89 for all the dimensions. Content validity was established through expert panel review and construct validity by factor analysis.

Mathematics Achievement Test (MAT): Mathematics performance was assessed by students' scores on the final examination for Class IX (maximum attainable score: 100). These national tests measure general mathematical competencies such as number operations, algebraic thinking, geometry, and problem solving.

3.4 Data Collection Procedure

After the appropriate institutional permissions were obtained and informed consent was secured, the students were administered the Multiple Intelligence Scale during a normal class session in the normal classroom in school. Research assistants were trained to supervise administration to ensure standardization. Final examination scores in mathematics were collected from school records.

3.5 Data Analysis

Correlational Analysis: Pearson product-moment correlation was calculated in order to investigate the overall relation between multiple intelligence and mathematics achievement.

Analysis of Associations: Chi-square (χ^2) tested the association between multiple intelligence levels (low, average, high) and the categories of mathematics achievement (low, moderate, high).

Regression Analysis: Multiple linear regression (all predictors entered simultaneously) was used to examine the unique contribution of nine intelligence dimensions to prediction of the dependent variable.

The regression model was:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \varepsilon$$

Where:

- Y = Mathematics Achievement
- X_1 to X_9 = Nine intelligence dimensions
- β_0 = Intercept
- β_1 to β_9 = Regression coefficients
- ε = Error term

The statistical significance was evaluated at 0.05 and 0.01 levels of the significance.

4. Results

4.1 Correlational Analysis

The result of the Pearson correlation coefficient showed that there was a positive and significant correlation between multiple intelligence and mathematics achievement ($r=0.240$, $p<0.01$, df=998). The strength of the correlation, while statistically significant, is relatively modest, and it indicates that 5.76% of variance in mathematics achievement is accounted for by overall multiple intelligence scores ($r2=0.0576$).

Table 1: Correlation between Multiple Intelligence and Mathematics Achievement

Variables	N	df	r value	Significance
Multiple Intelligence	1000	998	0.240**	p=0.000
Mathematics Achievement	1000	998		

Note: **p<0.01; Table value at p=0.01, df=998 is 0.066

This result confirms the prediction that multiple intelligence is positively associated with mathematics achievement. Wide intelligence profile students were more likely to have better mathematics results.

Nonetheless, the modest size of the correlation suggests that multiple intelligence is really just one of a vast number of variables affecting mathematics achievement.

4.2 Association Analysis

A Chi-square test was conducted to examine whether intelligence levels and achievement categories are related in a statistically significant way beyond what could be expected by chance. The results showed that there was a significant relationship between the multiple intelligence levels and the categories of mathematics achievement ($\chi^2=14.06$, df=4, $p<0.01$).

Table 2: Association between Multiple Intelligence and Mathematics Achievement

Mathematics Achievement	Multiple Intelligence Levels			Total
	Low	Average	High	
Low	37 (42.59)	24 (21.4)	59 (65)	120
Average	82 (87.43)	439 (435.8)	169 (172.76)	690
High	51 (47.97)	81 (84.8)	58 (73.225)	190
Total	170	544	286	1000

Note: $\chi^2=14.06$, df=4, $p<0.01$; Expected frequencies in parentheses; Table value at 0.01 level=13.277

The observed frequencies differ significantly from the expected frequencies, and this suggests that there is a systematic relationship between level of intelligence and category of achievement. Students with high multiple intelligence score have more chance of getting high performance in mathematics. This pattern of association backs up the models of differentiated instruction that acknowledge heterogeneous intelligence profiles in students.

4.3 Multiple Regression Analysis

The unique predictive effects of nine dimensions of intelligence were simultaneously investigated by using multiple linear regression analysis. The regression at the overall level was significant, with a large effect size ($R=0.913$, $R2=0.8335$, $F(9,990)=551.78$, $p<0.01$), suggesting that the dimensions of intelligence are able to explain collectively 83.35% of variance in mathematics achievement.

Table 3: Multiple Regression Analysis Predicting Mathematics Achievement

Intelligence Dimension	B	SE	β	t	Sig.
Constant	21.599	0.704	-	-30.69	0.000
Linguistic	-0.050	0.005	-0.059	-9.88	0.000**
Logical-Mathematical	0.596	0.024	0.459	25.01	0.000**
Bodily-Kinesthetic	0.010	0.002	0.030	4.59	0.000**
Spatial	0.215	0.009	0.270	24.35	0.000**
Musical	0.004	0.010	0.020	6.28	0.000**
Naturalistic	0.010	0.007	0.010	5.12	0.000**
Interpersonal	0.025	0.006	0.026	3.91	0.000**
Intrapersonal	0.385	0.295	0.295	16.50	0.000**
Existential	0.010	0.003	0.050	8.41	0.000**

Note: $R=0.913$, $R^2=0.8335$, Adjusted $R^2=0.8320$; $^{**}p<0.01$; Dependent Variable: Mathematics Achievement

The fitted regression equation is:

$$\mathbf{Y = 21.599 - 0.05X_1 + 0.596X_2 + 0.01X_3 + 0.215X_4 + 0.004X_5 + 0.01X_6 + 0.025X_7 + 0.385X_8 + 0.01X_9}$$

Where Y is the mathematics achievement, and X1, X2, …, X9 are linguistic, logical-mathematical, bodily-kinesthetic, spatial, musical, naturalistic, interpersonal, intrapersonal, and existential intelligence, respectively.

Key Findings:

1. Logical-Mathematical Intelligence (β=0.459): was the strongest predictor, in line with theoretical expectations. A one standard deviation increase in logical-mathematical intelligence predicts a 0.459 standard deviation increase in mathematics achievement after controlling for other intelligences.

2. Intrapersonal Intelligence (β=0.295): The second most robust predictor that draws our attention to the importance of metacognitive awareness, self-understanding, and self-regulation in the context of learning mathematics. Students with awareness of their cognitive processes and who regulate learning strategies are more successful in mathematics.

3. Spatial Intelligence (β=0.270): Third strongest predictor, which further confirms the importance of spatial visualization in mathematical reasoning, especially in geometry, graphing and in the conceptual understanding of mathematical relations.

4. Linguistic Intelligence (β=-0.059): TIS unexpectedly showed a negative coefficient, implying an inverse relationship while controlling for other intelligences. Such a surprising result might be due to suppression effects or mean that putting too much emphasis on verbal-linguistic processing could disrupt mathematical-symbolic processing if controlling for other intelligences.

5. Remaining Intelligences: Bodily-kinesthetic, musical, naturalistic, interpersonal, and existential intelligences had positive coefficients though of smaller magnitudes, suggesting that these intelligences also made small but significant contributions to mathematics achievement.

The very high R-square (0.8335) suggests that the dimensions of multiple intelligences are, together, explaining a large portion of variance of mathematics achievement, which is in line with the prediction of Gardner that mathematical learning draws on a variety of cognitive domains rather than relying solely on what is considered as traditional psychometric intelligence.

5. Discussion

5.1 Interpretation

This research result indicates that multiple intelligence has a significant effect on mathematics achievement of secondary school students. A positive association ($r=0.240$) suggests that those students with multiple intelligences outperform. The high association ($\chi^2=14.06$) confirms a strong association between intelligence and level of achievement. The regression results show that the dimensions of intelligence account for 83.35% of the variance in achievement, which is much higher that that achieved by the traditional measures. Logical-mathematical intelligence emerged as the most powerful predictor, followed by intrapersonal and spatial intelligences, indicating the importance of self-awareness and visualization. There is a slight negative effect of linguistic intelligence which might be related to analytical interference. Mild contributions were observed for other intelligences, indicating that learning mathematics may involve multiple cognitive abilities rather than just thinking logically.

5.2 Limitations

This study has limitations. The four cross-sectional panels cannot account for causality. Intelligence may have been bias by self-report.

Sampling from one district restricts the extent to which the results can be generalized. Test scores might not reflect all of a student's mathematical abilities. Despite the high predictability (R^2 = 0.8335), this finding also implies that there are unexplained variances, which suggests that other factors such as motivation, quality of teaching, and prior knowledge may play a role in achievement.

5.3 Policy Recommendations

1. For any and all lectures in mathematics, the teacher should employ a variety of delivery methods (lecture, visual aides, hands-on activity, group work, reflection) to address varied student learning preferences.
2. Schools should focus on evaluating the types of intelligence students have and adjust the teaching accordingly, instead of segregating based on mathematics ability.
3. Students need to learn to plan, monitor, and evaluate their thinking as they problem solve in order to enhance their understanding and performance.
4. Teaching mathematics should be based on visual graphic organizers such as charts, diagrams and three-dimensional solutions that can be presented by using interactive tools.
5. What's assessed should be explanations, diagrams, models, team work, and reflections—not just timed tests of computations and problem solving.
6. Teachers require professional development related to multiple intelligence-based assessment and instruction in order to successfully implement effective math instruction.
7. The curriculum should have opportunities for learning that are linguistic, spatial, physical, interpersonal and intrapersonal in nature as well as opportunities for learning that are covered under the mathematical intelligence.

6. Conclusion

Three is the number of conclusions that can be drawn. A positive correlation between $r=0.240$ and association $\chi^2=14.06$ confirm that there are links between multiple intelligences and mathematics performance. Logical-mathematical, intrapersonal, and spatial, which indicate joint cognitive functions. The high degree of explained variance ($R^2=0.8335$) implies that multiple intelligences capture mathematical ability better than single dimension based measures.

The results highlight variation in cognitive involvement and metacognition during learning. Mathematics performance is malleable and can be enhanced with instruction. Future studies should be longitudinal, experimental, qualitative, and cross-cultural in order to confirm and expand these findings.

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