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Influence of metacognition and locus of control on mathematical problem-solving ability of eighth grade students

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Abstract
The descriptive study aims to find out the influence of metacognition and locus of control on mathematical problem-solving ability of eighth grade students. the descriptive study collected data from a stratified random sample of 642 eighth grade students (boys = 307; girls = 335) by administering a series of standardized psychometric instruments *viz.*, the Mathematical Problem-Solving Ability Test, Style of Learning and Thinking, Metacognitive Awareness Scale, and the Malayalam version of Internal-External Locus of Control Scale. The data were subjected to linear regression analysis and one-way analysis of variance with the help of SPSS. The results brought out that metacognition and internal locus of control have significant influence on the mathematical problem-solving ability of eighth grade students with left hemisphericity and right hemisphericity. Though the influence of metacognition on the mathematical problem-solving ability of the students with integrated hemisphericity is significant, internal locus of control has no significant influence on their mathematical problem-solving ability.

Keywords: Mathematical problem-solving ability, hemisphericity, metacognition, locus of control

1. Introduction

Problem-solving has great importance in the learning of mathematics in our schools. The primary goal of mathematics teaching and learning is to develop the ability to solve a wide variety of complex mathematics problems. The art of problem-solving is the heart of mathematics. Acquiring mathematical problem-solving ability is likely to improve and develop the standard ability to resolve real-life problems (Reys, Lindquist, Smith, & Suydam, 2001) [1]. Studies on metacognition have continuously proven the effectiveness of metacognitive strategies on mathematical problem-solving (e.g., Guner & Erbay, 2021; Casaig, 2019) [2, 4]. In spite of the repeated research evidence on the effectiveness of metacognitive strategies on problem-solving, mathematics remains as the most difficult school subject. The reasons behind this phenomenon may be low levels of metacognitive skills among students (Khasawneh, Alkhawaldeh & Al-Khasawneh, 2020; Jaleel & Premachandran, 2016) [3, 5]. Furthermore, it was also reported that though the students have moderate levels of metacognitive thinking skills, they lack the skill of using metacognition in problem-solving (Aljaberi & Gheith, 2015; Al-Hamouri & Abu Mokh, 2011) [6, 7]. Added to this, research evidences also available to show that teachers do not encourage students to employ metacognitive strategies in classrooms (Rahman, Yasin, Ariffin, Hayati & Yusoff, 2010) [8].

Studies have repeatedly brought out the positive correlation between academic achievement and internal locus of control of learners (e.g., Chinedu & Nwizuzu, 2021: Afshan, Khanam & Kalsoom, 2020) [9, 10]. The association between locus of control and various problem-solving abilities have also been established by a few authors (e.g., Konan, 2013; Ucar & Duy, 2013) [11, 12]. The predictive power of internal locus of control on the ability of people in solving different problems have been also reported by researchers like Cakır (2017) [13] and Girdhar (2014) [14]. The direct positive effect of internal locus of control on mathematical problem-solving ability was found by Kalamu, Hulukati, Badu and Panai (2018) [15]. Hill (2016) [16], however, found no association between locus of control and discipline wise achievement. Choudhury and Borooah (2017) [17], on the contrary, found a significant association between academic achievement and external locus of control among college students. Christian-Ike and Okoli (2021) [18] found even negative correlation between locus of control and academic achievement.

In the light of the persisting research controversy on the relationship of problem-solving ability to metacognition and locus of control, this study was taken up to find out the influence of these variables on mathematical problem-solving ability.

2. Objectives of the Study

2.1 The study has the following specific objectives in view

1. To find out influence of metacognition on mathematical problem-solving of eighth grade students with different cerebral hemisphericity.
2. To find out influence of locus of control on mathematical problem-solving of eighth grade students with different cerebral hemisphericity.

3. Hypotheses of the Study

3.1 The following null hypotheses were tested for the study

1. Metacognition has no significant influence on mathematical problem-solving ability of eighth grade students with different hemisphericity.
2. Locus of control has no significant influence on mathematical problem-solving ability of eighth grade students with different hemisphericity.

4. Methodology of the Study

1. **Method:** The descriptive study followed normative-survey method to answer the research questions.
2. **Population:** Entire students studying in Standard VIII of Government schools, Aided private schools, and Unaided private schools that are affiliated to Kerala Board of public Examinations, Govt. of Kerala constituted the population of the present study.
3. **Sample for the study:** A stratified random sample of 642 eighth grade students were drawn from government, aided and unaided schools located in four districts, *viz*., Thiruvananthapuram, Ernakulam, Thrissur and Kozhikode, of Kerala. The sample consisted of 307 boys and 335 girls.
4. **Tools used:** The data were collected by administering the following standardized instruments: (i) Mathematical Problem-Solving Ability Test [MPAT] (Annamma & Arjunan, 2019 [20] (ii) Style of Learning and thinking [SOLAT] (Venkataraman, 1994) [19], (iii) Metacognitive Awareness Scale [MAS] (Jayaprabha, 2013), and (iv) The Malayalam version of Internal-External Locus of Control Scale (IELCS), (Arjunan & Abraham, 2003) [21].
5. **Procedure:** The tools were administered under standardised classroom conditions, the response sheets were scored manually. The scores were consolidated with the help of a spreadsheet, and subjected to statistical analysis by using SPSS (version 20.0 for Windows).
6. **Statistical techniques:** Linear regression analysis and one way ANOVA were the inferential statistical techniques employed for testing the hypotheses.

5. Analysis and Interpretation

The influence of metacognition and locus of control on the mathematical problem-solving ability of eighth grade students by taking the sample as total and also as sub-groups based on the mode of hemisphericity (Left hemisphericity, Right hemisphericity, and Integrated hemisphericity), followed by testing of the hypotheses.

5.1 Influence of metacognition on mathematical problem-solving ability of students with different hemisphericity

In order to find out the influence of Metacognition (MC) on Mathematical Problem-solving Ability (MPA), linear regression analysis was performed by taking metacognition as the predictor variable and mathematical problem-solving ability as criterion variable. The Model Summary of the linear regression analysis performed in this regard is given in Table 1.

Table 1: Model summary of linear regression analysis for the total sample (MC X MPA)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.577[a]	.333	.332	1.979
a. Predictors: (Constant), MC				

The value of R^2 estimated for the model shows that 33.3% of the total variation in mathematical problem-solving ability of eighth grade students can be explained by their metacognition. Further, one-way ANOVA was carried out to find out the significance of the influence exerted by metacognition on mathematical problem-solving ability, the data and result of the analysis of variance is given in Table 2.

Table 2: Significance of variance due to metacognition in mathematical problem-solving ability of total sample (Summary of ANOVA).

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1250.865	1	1250.865	319.501	.000[a]
	Residual	2505.635	640	3.915		
	Total	3756.500	641			
a. Predictors: (Constant), MC			b. Dependent Variable: MPA			

The F-ratio estimated is significant beyond 99.9% confidence interval showing that the regression model predicts the dependent variable significantly well ($F = 319.501$; $p<.001$). To put differently, the metacognition (predictor variable) has significant influence on mathematical problem-solving ability (criterion variable) of eighth grade students. The linear regression analysis was further repeated for the sub-groups of students with different brain hemisphericity, so as to find out the influence of metacognition on mathematical problem-solving ability for each group. Table 3 presents the consolidated model summary of the linear regression analyses for students with different brain hemisphericity.

Table 3: Model summary of linear regression analysis for students with different hemisphericity (MC X MPA)

Hemisphericity	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Left	1	.630[a]	.397	.394	1.952
Right	1	.542[a]	.294	.290	1.955
Integrated	1	.549[a]	.302	.299	2.005
a. Predictors: (Constant), MC					

As evident from the R-square values estimated for different hemisphericity modes show that students with left hemisphericity ranks first with 39.7% of the total variation in mathematical problem-solving ability that can be explained by metacognition, followed by students with integrated hemisphericity (30.2% of variation) and lowest by students with right brain hemisphericity (29.4%). In order to find out the significance of the influence exerted by metacognition on mathematical problem-solving ability of students with different brain hemisphericity, one-way analysis of variance was conducted. The data and result of the one-way ANOVA conducted for each group are consolidated in Table 4.

Table 4: Significance of variance due to metacognition in mathematical problem-solving ability for different hemisphericity (Summary of ANOVA)

Hemisphericity	Model	Sum of Squares	df	Mean Square	F	Sig.
Left	Regression	527.328	1	527.328	138.330	.000
	Residual	800.540	210	3.812		
	Total	1327.868	211			
Right	Regression	304.059	1	304.059	79.533	.000
	Residual	730.200	191	3.823		
	Total	1034.259	192			
Integrated	Regression	408.564	1	408.564	101.599	.000
	Residual	945.014	235	4.021		
	Total	1353.578	236			

The results of the one-way ANOVA shows that all the F-ratios estimated are significant beyond 99.9% confidence interval, revealing that the corresponding regression models are capable of predicting the mathematical problem-solving ability of students with left hemisphericity (F = 138.330; *p*<.001), right hemisphericity (F = 79.533; *p*<.001), and integrated hemisphericity (F = 101.599; *p*<.001) significantly. Putting differently, metacognition has significant influence on mathematical problem-solving ability of eighth grade students with different modes hemisphericity.

5.2 Influence of locus of control on mathematical problem-solving ability of students with different hemisphericity

Linear regression analysis was carried out to find out the influence of locus of control on mathematical problem-solving ability by taking the former as the predictor variable and the later as the criterion variable. The Model Summary of the linear regression analysis conducted in this context is given in Table 5.

Table 5: Model summary of linear regression analysis for the total sample (LC X MPA)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.222[a]	.049	.048	2.362
	a. Predictors: (Constant), LC			

The estimated R^2 is small, which indicate that only 4.9% of the total variation in mathematical problem-solving ability of eighth grade students could be explained by their internal locus of control. In order to find out whether internal locus of control of the students exert any significant influence on their mathematical problem-solving ability, one-way analysis of variance was performed. Table 6 presents the summary and result of the one-way ANOVA.

Table 6: Significance of variance due to locus of control in mathematical problem-solving ability of total sample (Summary of ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	185.118	1	185.118	33.174	.000[a]
	Residual	3571.382	640	5.580		
	Total	3756.500	641			
a. Predictors: (Constant), MC			b. Dependent Variable: MPA			

The F-value estimated is large enough to be significant beyond 99.9% confidence interval, disclosing the ability of the regression model to predict the criterion variable significantly (F = 33.174; *p*<.001). In another words, internal locus of control exerts significant influence on mathematical problem-solving ability of learners in grade eighth.

The differential effect of brain hemisphericity on the influence of internal locus of control on the mathematical problem-solving ability of the students were examined by repeating the linear regression analysis for the sub-groups of students based on their brain hemisphericity. The consolidated model summary of the linear regression carried out for students with various modes of hemisphericity is presented in Table 7.

Table 7: Model summary of linear regression analysis for students with different hemisphericity (LC X MPA)

Hemisphericity	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Left	1	.301[a]	.091	.086	2.398
Right	1	.235[a]	.055	.050	2.262
Integrated	1	.086[a]	.007	.003	2.391
[a.] Predictors: (Constant), LC					

The R^2 values estimated for different hemisphericity modes demonstrate that learners with left hemisphericity ranks first with 9.1% of the total variation in explaining the mathematical problem-solving ability by their internal locus of control scores. Students with integrated hemisphericity is the weakest where only 0.7% of the variation in mathematical problem-solving ability could be explained by the scores of internal locus of control. The R-square value obtained for students with right hemisphericity shows that 5.5% of the variability can be explained by the predictor variable. One-way ANOVA was further performed to find out the significance of the influence exerted by internal locus of control on mathematical problem-solving ability of students with various modes of hemisphericity. The consolidated results of the one-way analysis of variance for different hemisphericity modes are presented in Table 8.

Table 8: Significance of variance due to internal locus of control in mathematical problem-solving for different hemisphericity (Summary of ANOVA)

Hemisphericity	Model	Sum of Squares	df	Mean Square	F	Sig.
Left	Regression	120.273	1	120.273	20.915	.000
	Residual	1207.595	210	5.750		
	Total	1327.868	211			
Right	Regression	57.271	1	57.271	11.196	.001
	Residual	976.988	191	5.115		
	Total	1034.259	192			
Integrated	Regression	9.917	1	9.917	1.734	.189
	Residual	1343.661	235	5.718		
	Total	1353.578	236			

The results of the one-way ANOVA show that the F-ratio estimated for left hemisphericity (F = 20.915; p<.001) and right hemisphericity (F = 11.196; p<.001) are significant. It shows that the regression model for students with left hemisphericity and right hemisphericity significantly predicts their mathematical problem-solving ability. The F-ratio estimated for students having integrated hemisphericity is not significant (F = 1.734; p>.05), showing that the regression model is not significantly predicts their mathematical problem-solving ability.

6. Conclusions

The result of the linear regression analysis performed to find out the influence of metacognition on mathematical problem solving ability demonstrated that the predictor variable exerts significant influence on the criterion variable (F = 319.501; p<.001) for the total sample and also for group of students with different modes of hemisphericity. The hypothesis formulated in this context, *viz*., Hypothesis-1 (metacognition has no significant influence on mathematical problem-solving ability of eighth grade students with different hemisphericity) is, therefore, rejected. The result of the linear regression analysis done to find out the influence of locus of control on mathematical problem solving ability exposed that the predictor variable exercises significant influence on the criterion variable (F = 33.174; p<.001) for the total sample and also for students with left hemisphericity (F = 20.915; p<.001) and right hemisphericity (F = 11.196; p<.001), but not for those with integrated hemisphericity (F = 1.734; p>.05). The hypothesis formulated in this context, *viz*., Hypothesis-2 (locus of control has no significant influence on mathematical problem-solving ability of eighth grade students with different hemisphericity) is, therefore, partially rejected. The study disclosed that metacognition and internal locus of control have significant influence on the mathematical problem-solving ability of eighth grade students with left hemisphericity and right hemisphericity. Though the influence of metacognition on the mathematical problem-solving ability of the students with integrated hemisphericity is significant, internal locus of control has no significant influence on their mathematical problem-solving ability.

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