

Cognitive Abilities in Mathematical Problem Solving of Future Elementary Teachers: A Causal-Comparative Research

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Abstract

The cognitive abilities in mathematical problem solving of 88 potential elementary teachers enrolled in the College of Education at Central Luzon State University in Nueva Ecija, Philippines, were examined in this causal-comparative analysis.

The study found out that the majority of the respondents were females, had graduated from public high school, lived in rural areas, did not participate in recreational activities, had parents with a high school diploma, and came from a low-income background. In terms of mathematical problem solving, the respondents have average cognitive abilities. As to the respondents' observed socio-demographic characteristics, ANOVA, Tukey HSD test, and multiple linear regression analysis revealed that participation in leisure activities, the mother's educational attainment, and monthly family income significantly affected and predicted the students' mathematical cognitive abilities.

This paper had pedagogical repercussions as well as suggestions for future research in this area.

Key-words: Causal-comparative Research, Cognitive Abilities, Future Elementary Teachers, Mathematical Problem Solving.

1. Introduction

Cognitive abilities are any mental capabilities that are used in the process of acquiring knowledge. These include reasoning, perception and intuition (Inhelder & Piaget, 1967).

The National Council of Teachers of Mathematics (2003) decided that the primary objective of a school mathematics program should be to grow independent learners. It is only possible, however, if students have acquired the requisite knowledge. Learning mathematics appears to entail formal

organizational thoughts contained in the concrete and formal stages, implying that cognitive abilities are needed.

Learners' cognitive abilities are assessed in a variety of ways, one of which is the use of the Test on Logical Operation (TLO). The key instrument of this analysis, the Test of Logical Operations (TLO) in Mathematics, was planned and constructed on the basis of Piaget's (1950) seven logical operations (classification, seriation, logical multiplication, compensation, ratio and proportional thinking, probability thinking and correlational thinking).

Several types of research were performed to assess mathematical cognitive abilities (Leongson & Limjap, 2003; Gamit, 2010; Pagay, 2008; Decano, 2017). In a study of cognitive abilities of college freshmen conducted by Leongson and Limjap (2003) and Gamit (2010), they discovered that freshmen fell into the concrete operational level, contrary to Piaget's belief that these college freshmen aged 16-19 years could perform logical operations with mastery. Both studies reported a troubling finding: students had an adequate understanding of problems involving logical multiplication but an inadequate understanding of problems involving the other six logical operations. Decano (2017) also looked into the cognitive ability of college students, finding that the vast majority of them are at the concrete operational level. Furthermore, Domingo (2018) found that the results of the same analysis in Grade 12 Senior High School students were consistent with the findings of Leongson and Limjap (2003), Gamit (2010), and Decano (2017). His results showed an even more troubling result: they had a poor understanding of probability thinking and insufficient understanding of the rest of the logical operations.

The studies above demonstrated that various learners' cognitive abilities in mathematics are a source of concern. However, there were few types of research on the factors that could influence their cognitive abilities in solving mathematical problems (Salangsang & Subia, 2020), which this study looked into. It examined the variables that influenced the cognitive abilities of future elementary teachers in solving mathematical problems.

2. Methodology

This research used a descriptive causal-comparative design to describe the profile and cognitive abilities in mathematics of the learners and investigate the difference in cognitive abilities of a group of respondents according to sex, type of high school graduated from, place of residence, engagement in recreational activities, educational attainment of the father, educational attainment of the mother,

and monthly family income. A causal-comparative design is a research design that seeks to find relationships between independent and dependent variables and the researcher's goal is to determine whether the independent variable affected the outcome, or dependent variable, by comparing two or more groups of individuals (Salkind, 2010).

Respondents of the study who were picked with the use of total enumeration sampling were all the 88 fourth-year Bachelor of Elementary Education students in the College of Education, Central Luzon State University (CLSU). It is situated in the Science City of Muñoz, Nueva Ecija, Philippines. CLSU is considered one of the renowned and prestigious state-institutions of higher learning in the country. It is designated by the Commission of Higher Education (CHED) as Center of Excellence in Agriculture, Agricultural Engineering, Biology, Fisheries, Teacher Education, and Veterinary Medicine. The University caters to students from different municipalities and nearby provinces in Region III.

This study used a questionnaire that included two (2) parts. The first part comprised the socio-demographic characteristics of the respondents such as sex, type of high school graduated from, place of residence, engagement in recreational activities, educational attainment of the father, educational attainment of the mother, and monthly family income. The second part was a validated teacher-made test developed by Gamit (2010) called the Test on Logical Operations (TLO) and it was adopted and modified for the purpose of this study. In measuring the respondents' cognitive level abilities (Subia, et al, 2020) in mathematical problem solving for each operation, the multiple scoring scheme proposed by Schoenfield (1982) was used. Respondents who scored in the mean range of 0-5.0 were given a qualitative description of poor, 5.1 to 10 points were below average, 10.1 to 15.0 points were average and 15.1 to 20.0 were outstanding.

To define the respondents in terms of socio-demographic characteristics and to assess the success and categorization of cognitive abilities in mathematical problem solving, descriptive statistics such as frequency, percentage and mean were used. In addition, a series of Analysis of Variance (ANOVA) tests were used to assess the differences in cognitive abilities in mathematical problem solving between groups of respondents based on socio-demographic factors. Non-dichotomous variables were also subjected to a post-hoc study using the Tukey HSD test. The important predictors of potential elementary teachers' cognitive abilities in mathematics were also determined using multiple linear regression analysis.

3. Results and Discussion

1. Respondents' Socio-Demographic Characteristics

The profile of 88 respondents was described in terms of sex, type of high school graduated from, place of residency, engagement in recreational activities, educational attainment of the father, educational attainment of the mother and monthly family income.

Table 1 - The Socio-demographic Characteristics of the Respondents

SOCIO-DEMOGRAPHIC CHARACTERISTICS	F (N=88)	%
Sex		
Male	20	22.73
Female	68	77.27
Type of High School Graduated From		
Public	64	72.73
Private	24	27.27
Place of Residency		
Rural	68	77.27
Urban	20	22.73
Engagement in Recreational Activities		
Engaged	43	48.86
Not Engaged	45	51.14
Educational Attainment of the Father		
Elementary	8	9.09
High School	43	48.86
College	31	35.23
Graduate Studies	6	6.82
Educational Attainment of the Mother		
Elementary	3	3.41
High School	41	46.59
College	28	31.82
Graduate Studies	16	18.18
Monthly Family Income		
Low Income	61	69.32
Middle Income	22	25.00
High Income	5	5.68

Sex

Most of the respondents were females (77.27%) as shown in Table 1. This attested to the notion that, in the country's educational system, teaching is predominated by females in all levels of education.

Type of High School Graduated From

The results showed that the majority of the respondents graduated from public high school with 64 elementary pre-service teachers or 72.73 percent. This result was similar to the report of the Department of Education in 2006 that almost all of the students were enrolled in public schools (93% of elementary students and 80% of secondary students).

Place of Residence

Most of the respondents came from rural residence (77.27%) and the remaining 22.73 percent indicated that they live in urban areas. This result revealed that the majority of the students in Central Luzon State University (CLSU) live in rural areas. Considering the location of CLSU, it is expected to cater to more local students coming from neighboring municipalities and provinces which are considered rural.

Engagement in Recreational Activities

Data revealed that the majority of the respondents (45 or 51.14%) were not engaged in recreational activities. Considering CLSU as an academic institution, the results affirmed that students are more on academics.

Educational Attainment of the Father

As presented in Table 1, almost half of the respondents (48.86%) had fathers who earned high school level of education which is lacking minimum requirement for employment. This denoted that the fathers of the respondents had low economic employability which may result in a lower family income. Thirty-one or 35.23 percent earned college degrees, while 6 or 6.82 percent finished master or doctoral degrees. The rest (9.09%) of the fathers of the respondents graduated elementary level.

Educational Attainment of the Mother

In terms of educational attainment of the mother, there was 41 or 46.59 percent of the respondents whose mothers finished high school level of education. Twenty-eight or 31.82 percent

earned college degrees, while 16 or 18.18 percent earned graduate studies. The rest (3.14%) of the respondents' mothers completed elementary level.

Monthly Family Income

Gathered data revealed that among the total number of the respondents, the majority (69.32%) had a monthly family income of Php0.00 – Php11, 914.50 which is considered low according to the Family Expenditure and Income Survey (2009) of Philippine Statistics Authority.

2. Respondents’ Cognitive Abilities in Mathematical Problem Solving

Table 2 - Cognitive Abilities in Mathematical Problem Solving

LOGICAL OPERATIONS	Mean	Mathematical Problem Solving Ability
Classification	10.82	Average
Seriation	10.15	Average
Logical Multiplication	14.69	Average
Compensation	13.83	Average
Ratio and Proportional Thinking	10.51	Average
Probability Thinking	6.30	Below Average
Correlational Thinking	8.93	Below Average
Overall Mean Score	10.74	Average

Table 2 shows that the respondents' cognitive abilities were average (Mean=10.74) in mathematical problem solving, particularly classification (Mean=10.82), seriation (Mean=10.15), logical multiplication (Mean=14.69), compensation (Mean=13.83), and ratio and proportional reasoning (Mean=10.51).

However, the findings were concerning, as the respondents scored below average in both probability and correlational reasoning (Mean=6.30 and 8.93, respectively). This means that in these two logical operations, the respondents, simply correctly interpreted the problem and provided an implicit and partial interpretation of the problem's solution, which matched Pagay's findings but contradicted Domingo's and Gamit's findings (2009).

3. Socio-Demographic Characteristics and Cognitive Skills Achievement in Mathematics

The socio-demographic characteristics such as sex, type of high school graduated from, place of residence, engagement in recreational activities, educational attainment of the father, educational

attainment of the mother and monthly income and the cognitive abilities in mathematics were gathered and analyzed using appropriate statistical tools to determine and explain differences in cognitive abilities using the afore mentioned variables.

Table 3 - Statistical Results in differences in Cognitive Abilities when the Students are Grouped According to Socio-Demographic Characteristics

SOCIO-DEMOGRAPHIC CHARACTERISTICS	Mean	Std. Dev.	df	F-value	p
Sex					
Male (n=20)	74.40	12.92	1,86	0.092	0.762
Female (n=68)	75.47	14.10			
Type of High School Graduated From					
Public (n=64)	74.69	12.10	1,86	0.358	0.551
Private (n=24)	76.67	17.71			
Place of Residency					
Rural (n=68)	74.79	13.15	1,86	0.294	0.589
Urban (n=20)	76.70	15.98			
Engagement in Recreational Activities					
Engaged (n=43)	79.09	15.44	1,86	7.090	0.009
Not Engaged (n=45)	71.53	10.91			
Educational Attainment of the Father					
Elementary (n=8)	70.13	6.33	3,84	0.650	0.585
High School (n=43)	74.49	13.13			
College (n=31)	77.16	14.91			
Graduate Studies (n=6)	75.23	19.67			
Educational Attainment of the Mother					
Elementary (n=3)	70.33 _b	9.07	3,84	11.83	0.000
High School (n=41)	69.32 _b	9.91			
College (n=28)	76.11 _b	13.84			
Graduate Studies (n=16)	89.75 _a	12.47			
Monthly Family Income					
Low Income (n=61)	72.07 _b	11.25	2,85	9.20	0.000
Middle Income (n=22)	79.55 _b	14.11			
High Income (n=5)	94.80 _a	21.14			

Engagement in Recreational Activities and Differences in Cognitive Skills Achievement

Using ANOVA, the results showed that there was a significant difference in cognitive abilities in mathematical problem solving between a group of respondents according to their engagement in recreational activities ($F_{(1,86)} = 7.090, p < 0.01, \eta^2 = 0.08$) indicating that respondents who were engaged (Mean = 79.09, SD = 15.44) in recreational activities tend to have higher cognitive abilities than those who were not engaged.

This result was consonant with the article written by Street et al. (2007), people who participate in sports clubs and organized recreational activities enjoy better mental health and cognitive ability, are more alert, more resilient against the stresses of modern living and promote intellectual advancement. Participation in recreational groups and socially supported physical activity is shown to reduce stress, anxiety and depression, and reduce symptoms of Alzheimer's disease. In addition, Wang et al. (2012) showed that leisure activities have a positive impact on cognition and dementia. This implies that the group of respondents who are engaged in recreational activities had a better mind and cognitive ability since they maintain to have good mental health.

Educational Attainment of the Mother and Differences in Cognitive Abilities

ANOVA was also utilized to determine the significant difference in cognitive abilities in mathematical problem solving between the group of respondents according to the educational attainment of their mother. Results of the ANOVA showed that there was a significant main effect of educational attainment of the mother to cognitive skills achievement in mathematics ($F_{(3,84)} = 11.83, p < 0.001, \eta^2 = 0.30$). A follow-up Post-Hoc analysis using the Tukey HSD test revealed that respondents whose mothers earned graduate studies (Mean = 89.75, SD = 12.47) had cognitive skills achievement in mathematics that was significantly higher than those respondents whose mother's educational attainment was elementary level (Mean = 70.33, SD = 9.07), secondary level (Mean = 69.32, SD = 9.91) and college-level (Mean = 76.11, SD = 12.47). Meanwhile, the cognitive abilities of those whose educational attainment of mothers were elementary, secondary and college-level were comparable based on the respondents' scores.

This result confirmed with Araza (2017) and Farooq et al. (2011). It was found out that the educational attainment of the parents particularly the mother could explain differences in cognitive abilities. As said by Wadley (2014), the amount of education one attains can predict children's success in reading and math. This may be added to the notion that it is the mother who is in touch when it comes to supervising her children, particularly in school. Parents with a higher level of education could be role models for their children to perform well in mathematics (Andaya, 2014). This finding was also supported by Araza (2017) where he found out that college students' math achievement was related to their mother's educational attainment. However, the results contradicted the findings of Hayali (2013) and Escarlos and Tan (2017) where they documented that the educational attainment of both mother and father was not related to academic performance.

Monthly Family Income and Differences in Cognitive Skills Achievement

To determine the significant difference in cognitive abilities in mathematical problem solving between a group of respondents according to monthly family income, ANOVA was also utilized. Results of the ANOVA showed that there was a significant main effect of monthly family income on cognitive abilities in Mathematics ($F_{(2,85)} = 9.198, p < 0.001, \eta^2 = 0.18$). A follow-up Post-Hoc analysis using the Tukey HSD test revealed that respondents who have high monthly family income (Mean = 94.80, SD = 21.14) were significantly higher than those who have low monthly family income (Mean = 72.07, SD = 11.25) and middle monthly family income (Mean = 79.55, SD = 14.11) in terms of cognitive abilities in Mathematics. Meanwhile, the cognitive abilities in Mathematics of respondents who have low monthly family income and middle family income were statistically comparable.

This finding was in line with Kirkup's (2008) research, which found that students with a high socioeconomic status performed better than middle-class students, and middle-class students performed better than students with a low SES. More specifically, Farooq et al. (2011) discovered that students' socioeconomic status had a substantial impact on their overall academic achievement as well as their mathematics achievement. The results implied that having a high monthly family income could affect cognitive abilities positively. This can be added to the notion that in a highly income-generated family, children were given a chance and were provided by an educationally rich and stimulating setting for the development of cognitive abilities of the children. However, it contrasted the findings of Escarlos and Tan (2017) and Alver (2005) where they found that monthly family income and academic performance were insignificantly related.

Other Insignificant Socio-Demographic Characteristics and Differences in Cognitive Skills Achievement

When the respondents were classified according to their sex, type of high school they graduated from, place of residence, and educational attainment of the father, a series of ANOVA was performed to assess the differences in cognitive abilities in mathematical problem-solving. The findings showed that sex ($F_{(1,86)}=0.092, p>0.05$), type of high school attended ($F_{(1,86)}=0.358, p>0.05$), residence ($F_{(1,86)}=0.294, p>0.05$), and father's educational attainment ($F_{(3,84)}=0.650, p>0.05$) had no important key impact on cognitive ability in Mathematics.

4. Conclusions and Recommendations

Most of the respondents: were females; graduated from public high school; came from rural residence; were not engaged in recreational activities; have parents whose highest educational attainment was high school, and belonged to a low-income family.

They have average cognitive abilities in mathematical problem-solving. Their Engagement in recreational activities affected positively the development of their cognitive abilities in mathematical problem-solving. This implicated that engagement in recreational activities could help individuals' cognitive abilities as these activities promote thinking and balance in physical and mental health. The educational attainment of the mother had also an impact on cognitive abilities in math. This implied that students whose mothers had high educational attainment have a tendency to perform cognitive abilities with proficiency. Moreover, high monthly family income affected the cognitive abilities of the students. This implied that having a high monthly family income could be an avenue to have high accessibility in learning materials and a conducive learning environment that promotes development and improvement of cognitive abilities in Mathematics.

Among the observed socio-demographic characteristics of the respondents, engagement in recreational activities, educational attainment of the mother and monthly family income predicted the cognitive abilities in mathematical problem-solving. This implied that the three significant predictors could be used in forecasting the cognitive abilities in Mathematics of students particularly the future elementary teachers.

Since students were found out to have below average in some logical thoughts, mathematics teachers need to create a learning environment, develop teaching strategies and engage students in various learning materials that develop logical-mathematical processes and promote cognitive skills. Teachers need to align their instruction with the cognitive demands and cognitive levels of their students. Teachers in basic education should focus on the cognitive development of the learners since their cognitive abilities and logical thinking skills (Subia, 2020) are starting to develop in this stage. Since one of the major findings was the effect of engagement in recreational activities, teachers must encourage students to get engaged in various recreational activities.

Learning is best accomplished when the teacher employs a range of teaching methods and evaluation tools; thus, teachers must use learning exercises that emphasize the improvement of students' cognitive abilities. Curriculum planners may revisit the mathematics curriculum and include the cognitive demand of the learners in developing exercises and activities. This study also suggests

promoting easy access to different learning materials and environments that promote learning and the inclusion of their parents in the academic development of the students.

Mathematics educators and educators of other disciplines should take the findings of this study seriously and conduct further studies on learner's cognitive development. The researchers recommend other researchers conduct a study on the cognitive development of learners. They are highly encouraged to conduct researches in cognitive skills achievement that may improve cognitive skills using experimental research design.

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