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Cognitive Skills in Basic Mathematics of College Freshmen in the Philippines

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Abstract

Many students consider mathematics as the most dreaded subject in their curriculum, so much so that the term "math phobia" or "math anxiety" is practically a part of clinical psychological literature. This symptom is widespread and students suffer mental disturbances when facing mathematical activity because understanding mathematics is a great task for them. This paper described the students' cognitive skills performance in Basic Mathematics based on the following logical operations: Classification, Seriation, Logical Multiplication, Compensation, Ratio and Proportional Thinking, Probability Thinking and Correlation Thinking as it serves a critical element of teaching and learning, that is determining the current position of the learners' mathematical capacity. Its implications for mathematics education were also revealed. A descriptive quantitative design was used in this study. The study included 1011 first-year college students from six state universities in the Philippines who were enrolled in the Bachelor of Science of Secondary Education Program during the first semester of the Academic Year 2019-2020. This study made use of the teacher-made test called the Test on Logical Operations. Findings revealed that the cognitive skills achievement of the first year BSE students from different state universities in the Philippines falls under the category of late concrete operational stage. As a result, students are unable to perform the logical operational skills expected of their age. At their age level, they are expected to be under the formal operational stage based on Piaget's stages of cognitive development. These findings revealed a weak mathematical education foundation among students which requires immediate attention. This reality should be recognized by educational planners and implementers when making curricular and other instructional decisions.

Keywords

Mathematics, Cognitive Skills, Cognitive, Basic Mathematics

1. Introduction

Many students consider mathematics as the most dreaded subject in their curriculum, so much so that the term "math phobia" or "math anxiety" is practically a part of clinical psychological literature. This symptom is widespread and students suffer mental disturbances when facing mathematical activity because understanding mathematics is a great task for them. Consistently, it has been discovered that mathematics anxiety affects a person's mathematics ability and attitudes toward mathematics, such as interest and confidence in learning mathematic [1]. Among all academic competencies, mathematics has been highlighted as a crucial talent for persons pursuing employment in science, technology, and engineering, as well as in the field of international leadership [2]. Education majors' academic performance, their teaching practices and attitudes, and the achievement of their future students can all be improved by reducing potential teachers' arithmetic anxiety and boosting their spatial abilities via the use of suitable techniques [3] [4].

Cognitive capacities are affected by several variables, including genes, the environment, and economics [5]. Cognitive abilities predict academic achievement; hence, schools that promote academic performance may also improve cognitive abilities [6]. Further, Earnings premiums would rise over time for people with significant beginning endowments in both cognitive and social abilities, with college-acquired cognitive skills increasing these assets [7].

The theory of constructivism finds relevance and continuity in the cognitive development theory when Piaget [8] theorized that intelligence is the basic mechanism of ensuring equilibrium in the relations between the person and his environment. Piaget further stressed that the mechanism underlying this process of increasing abstraction, interiorization, and coordination is reflecting abstraction. These abilities enable students to categorize new issues into cognitive schema and then transfer content and procedural knowledge from known schema to new difficulties [9].

Understanding that the majority of cognitive growth gains occur in the first two years has significance for both community college administrators and administrators of four-year colleges and universities [10]. Thus, teaching nowadays should have far-reaching implications in order to assist students to reach the appropriate cognitive level that matches their biological age. This present picture of Philippine schools' human products in national and international surveys is very alarming. To rationalize this observation, this study was conducted to discern what specific level of cognitive skill the freshman college students possess using Piaget's logical operations. Using these insights, this study administered a test developed by researchers in accordance with Test on Logical Operations (TLO) that had been validated by experts and had its reliability analyzed.

2. Objectives of the Study

This paper described the students' cognitive skills performance in Basic Mathe-

matics based on the following logical operations: Classification, Seriation, Logical Multiplication, Compensation, Ratio and Proportional Thinking, Probability Thinking and Correlation Thinking. It also aimed to describe the implications for mathematics education, which would serve as the bases for various curricular and instructional decisions.

3. Methodology

This paper used a descriptive quantitative design. It further concerns the condition or relationship that exists, practices that prevail, and beliefs and processes that are going on, effects that are being felt or trends that are developing [11]. The study included 1011 first-year college students from six state universities in the Philippines who were enrolled in the Bachelor Science of Secondary Education Program during the first semester of the Academic Year 2019-2020. This study made use of the teacher-made test called the Test on Logical Operations. The Test on Logical Operations (TLO) is a test which covers selected topics in Basic Mathematics such as integers, fractions, decimals, percentages, geometry, and laws of exponent. It was designed and constructed on the basis of Piaget's seven logical operations which aimed to identify the students' level of cognitive skills achievement in Basic Mathematics (Refer to Appendix). Thus, **Table 1**, a rubric for scoring proposed by Raven [12] was used.

In describing the students' cognitive skills performance in the TLO per logical operation, **Table 2**, the multiple-count scoring scheme proposed by Schoenfield [13] was used.

Table 1. Scoring continuum for test of logical operations in mathematics.

Score	Interpretation
0	Made no attempt to solve the problem
1	Made little attempt in the form of sketches, jotting down needed relationship, jotting down needed data; or overtly explaining how to solve the problem
2	Showed understanding of the problem by the representations made and early attempts to solve the problem; problem solved about halfway
3	Made great progress in the solution. Problem is nearly solved, and solution is correct but minor errors are committed
4	Problem is fully correctly solved

Table 2. Mean score interpretation.

Mean Score	Qualitative Description
0 - 5.0	Low Understanding
5.1 - 10.0	Insufficient Understanding
10.1 - 15.0	Sufficient Understanding
15.1 - 20	Complete Understanding

To determine the cognitive stage of students based on Piaget's seven logical operations, the results of the TLO were categorized as follows in **Table 3**, as adapted from the study of Raven [12].

4. Results and Discussion

Table 4 summarizes students' performance in each of the seven logical operations. Results showed that the students had sufficient understanding in logical multiplication, insufficient understanding in classification, seriation, compensation, and correlational thinking, and had low understanding in ratio and proportional thinking and probability thinking.

Moreover, the lowest mean (1.66) in probability thinking strongly indicates the weakness of the students in this category of logical operation. In general, students had insufficient understanding on the logical operation as indicated by a grand mean of 6.89. Evidenced by [14], these insufficiencies in other logical processes were linked to their misunderstandings of some mathematical words, misreading of the issues, poor comprehension, poor problem-solving, and overall poor performance in mathematics. Another study of [15] concluded that when it comes to fraction operations, college students share the same misconceptions as elementary school students.

To describe the cognitive stage of students based on their test scores using the categorization, the test scores are presented in **Table 2** for the purpose of categorizing the data. Respondents were categorized according to their state university and labeled A, B, C, D, E, and F for confidentiality purposes. Their mean scores were tabulated and interpreted in accordance with the Cognitive Skills Achievement of Students adopted from the study of Raven [12].

Results revealed in **Table 5** show that majority of the BSE students from different state universities in the Philippines had cognitive skills achievement categorized within the late concrete operational stage. This shows that expected the cognitive skills achievement among students in the tertiary level did not match their actual cognitive abilities. Based on Piaget's seven logical operations, the students showed understanding of the problems given on each logical operation by the presentations and early attempts that they made to solve all the problems. They acted on the problem and were able to exhibit logical operation skills on few items. They were able to solve more problems that required the use of logical operations on the basic mathematical concepts, thus the scores gained were better.

Table 3. Cognitive skills achievement of students.

Total Score	Cognitive Stage
0 - 35	Early Concrete
36 - 70	Late Concrete
71 - 105	Early Formal
106 - 140	Late Formal

Table 4. Summary of students' cognitive performance in the seven logical operation.

Logical Operations	Overall Mean	Verbal Interpretation
Classification	9.48	Insufficient Understanding
Seriation	8.95	Insufficient Understanding
Logical Multiplication	10.37	Sufficient Understanding
Compensation	6.59	Insufficient Understanding
Ratio & Proportional Thinking	3.96	Low Understanding
Probability Thinking	1.66	Low Understanding
Correlational Thinking	7.23	Insufficient Understanding
Average	6.89	Insufficient Understanding

Table 5. Summary table of student's stages of cognitive development.

State University	Mean Score	Cognitive Stage
A	54.28	Late Concrete
B	50.06	Late Concrete
C	45.75	Late Concrete
D	49.76	Late Concrete
E	44.77	Late Concrete
F	44.78	Late Concrete
Overall	48.23	Late Concrete

There were major inconsistencies though in the solutions, just like those who belonged to the early concrete stage. There was no strong evidence of attainment of the desired achievements in mathematics at the formal level. Also, students under this category showed incomplete solutions to the problems. While the solutions can be considered logical, essential errors were committed. Students were able to pursue the sub goal but failed to arrive at the main goal of the problem. Thus, [16] demonstrates, in terms of assistance to students, that instructors' affective support may be crucial for the students' cognitive, emotional, and motivational well-being, as it improves enjoyment, self-efficacy, and academic effort in mathematics. Simple improvements to teaching based on the ideas provided here are expected to boost the effective use of manipulatives in mathematics training and improve students' problem-solving, critical thinking, and mathematical learning results [17]. Such as, utilizing technology in the teaching and learning process is a relatively efficient and cost-effective method for encouraging students to engage in cognitively demanding tasks [18].

5. Conclusions

The cognitive skills achievement of the first year BSE students from different

state universities in the Philippines falls under the category of late concrete operational stage. At their age level, they are expected to be under the formal operational stage based on Piaget's stages of cognitive development. As such students can't perform the logical operational skills expected for their age.

Student's ability to use Piaget's logical operations has not been fully developed as manifested in their ability to solve word problems involving the seven logical operations. They have low understanding in probability thinking where the students are found weakest. It is in logical multiplication that students have achieved sufficient understanding; however, their overall cognitive skills performance is categorized under insufficient understanding. Insufficient understanding of the students in all seven logical operations can be attributed to their misconceptions on some mathematical terms, misinterpretation of the problem, and poor language comprehension skills.

The highest percentage of students falls under the late concrete operational stage, and the very least percentage falls under the late formal operational stage. This study has supported Piaget's theory of cognitive development, *i.e.*, individuals go through cognitive stages and in the process, not all individuals/learners successfully reach the highest stage.

The various performances of students along the seven logical operations are as follows: low understanding in ratio and proportional thinking and probability thinking; insufficient understanding in classification, seriation, compensation, and correlational thinking; and sufficient understanding in logical multiplication. The cognitive stage of students which falls under the late concrete stage is attributed to their insufficient understanding of logical operations.

6. Recommendations

Since students should gain expertise in problem solving and be aware of the various logical operation processes, mathematics teachers need to create a learning environment that develops logical mathematical processes and the formal reasoning skills. They need to align the cognitive demands of their instruction with the cognitive levels of their students. Learning is best achieved when the teacher uses a variety of teaching strategies, thus there is a need for teachers to employ learner-centered teaching strategies that focus on the development of students' thinking skills. Using alternative assessments aside from the pencil and paper test should be one of their major concerns to cater to the diverse learners with unique characteristics.

Cognitive achievement is a serious matter, especially for students who aspire to be teachers someday. Entry/admission policy, as well as retention policy for the bachelor of Secondary Education program should be strictly implemented by school administrators. First year college students are supposed to be at the formal operational stage based on Piaget's theory. Educational planners should therefore recognize this reality when making curricular and other instructional decisions, hence they should look closely into the needs of the students and design their curriculum with those needs in mind.

7. Implications of the Study

From the results, it is quite alarming that majority of the students did not meet the expected operational tasks. The findings showed that students had sufficient understanding and can perform problems in logical multiplication but not on problems requiring the other six logical operations.

Several theories of development such as those Freud's psychoanalytical theory, Erikson's psychosocial development theory, Piaget's theory of cognitive development and Kohlberg's theory of moral development describe children with ages 12 and above are "preparing for an economic career with knowledge gained from academic exposure".

Mathematics education aims to develop the learners' higher order, analytical, and critical thinking skills. But if the students are at the concrete level, it is impossible to achieve this goal without the proper remediation, intervention and proper procedure to bridge the gap. As one knows that the concrete level corresponds to the elementary school years, the teacher has to see that curricular content instructional procedures are attuned to the pattern of thought characteristic of learners in particular stage of development. This can be done by recognizing the learners' different intellectual potentials, skills and abilities. With these considerations in mind, the teacher should design her instructional plan coinciding with the learner's abilities. It implies that the teacher has to select and provide appropriate learning experiences whereby the learners can discover relationships between elements in various situations and understand them as a whole in an organized and unified pattern. Hence, appropriateness and effectiveness of teaching lie in the learning situation that the teacher encounters. This means that if the teacher hopes to succeed she must be knowledgeable of alternative approaches to teaching.

8. Ethical Considerations

In this study, the researcher considered various ethical issues. Before administering the test, the researcher ensured that the respondents' respective authorities had granted permission for the study. In addition, respondents were required to sign an informed consent form in order to take part in the study. In the event that respondents chose to withdraw from the test, the researcher emphasized that they were under no obligation to do so and that there would be no negative repercussions. In addition, the researcher ensured that neither the school nor the participants incurred any costs as a result of the study.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix

TEST ON LOGICAL OPERATIONS IN BASIC MATHEMATICS

Name of Student:_____

Course/Year:_____

Age:_____

School:_____

General Directions:

This instrument is designed to evaluate your cognitive skill achievement in Basic Mathematics using jean Piaget's Logical Operations. All items included here are taken up in your Mathematics subject during your first year, first semester. Read and analyze carefully all the problems. Determine what is/are given and solve for what is/are being asked. Show your solutions on the answer sheet provided.

Specific Directions:

1) Go over the pages of the test instrument for the missing pages and take note all the corrections if there are.

2) This is a one-and-a-half hour test, so take your time. If you do finish ahead of time allotted, review your work.

3) Systematize your solutions and try to avoid erasures.

4) If you have any question, raise your hand and the proctor will approach you.

5) If done, pass the test instrument together with your answer sheets.

I. CLASSIFICATION

1) Determine the least amount in the following number.

0.1, 0.02, 0.003, 0.004, 0.005

2) On the following rates, which gives the biggest profit?

1%, 0.8%, 0.05%, 2%, 0.9%

3) Which of the following is arranged in ascending order?

Ones, tenths, millionths, thousandths, hundredths

Ones, tenths, hundredths, thousandths, millionths

Ones, tenths, thousandths, hundredths, millionths

Millionths, thousandths, hundredths, tenths, ones

Millionths, hundredths, thousandths, ones, tenths

4) Which of the following has the biggest place value?

Millionths, Thousandths, Hundredths, tens, ones

5) Which of the following numerical statement if correct?

$0.1 = 0.06$

$0.1 = 0.06$

$0.1 > 0.06$

$0.1 \geq 0.06$

$0.1 < 0.06$

6) If 0.5 is raised to a power, which of the following exponents will give the greatest answer?

0, 1, 2, 3, 4

7) Determine the fraction which does not belong to the group.

1/4, 2/8, 3/12, 4/6, 7/28

8) Which of the following has the greatest length?

1/2 feet, 1/4 yard, 5 inches, 1/3 meter, 1 decimeter

9) Arrange the following in descending order and find the first number.

40%, 4%, 0.044, 0.4%, 0.44

10) Given the following numbers, determine the last number when arranged from highest to lowest.

10%, 8%, 13%, 0.50%, 0.9%

II. SERIATION

1) Determine the fifth number in the progression.

2, 3, 5, 7, _____

2) Give the next value in the sequence of number.

−1, 4, −27, 256, _____

3) Determine the next number in the series.

0.1, 0.6, 1.1, 1.6, _____

4) What is the next possible number in the following sequence?

1%, 3%, 4%, 12%, 13%, _____

5) What is the third possible number in the sequence?

0.5, 0.6, _____, 1.1, 1.5

6) Find the next two numbers in the pattern.

1, 3, 6, 10, _____, _____

7) Find the next two numbers in the following series.

1, 1/4, 1/7, 1/10, _____, _____

8) What is the middle number in the following sequence?

10% of 50, 20% of 20, _____, 40% of 5, 50% of 2

9) Write the next number in the series.

1, 0.5, 0.25, 0.125, _____

10) Name the next three numbers in the progression.

1/2%, 2/4%, 3/6%, 4/8%, _____, _____, _____

III. LOGICAL MULTIPLICATION

1) The length of the curtain is twice its width. If the curtain is 8 feet long, how wide is the curtain?

2) Annie bought 8 rolls of film for her camera. If each roll costs P38.75, how much does she pay for the film?

3) A basketball player makes 2 three-point shot and 2 two-point shot in every quarter of the game. How much score does he make in four—quarter game?

4) How much is 6% of P150.00?

5) A family spends 1/2 of the total earnings for food, 1/4 for children's education and 1/4 for miscellaneous expenses. If the family's total earnings is P23,000 a month, how much do they spend for education?

IV. COMPENSATION

1) What is the equivalent of 0.75 in percent?

2) Two quarts of paint cost P198.00. Find the cost of 3 quarts.

3) 10% of 100 is equivalent to 5% of what number?

4) If a > b, which of the following symbols makes the mathematical statement correct.

$5 \times (-b) > 10 \times a$

$5 \times (-b) < 10 \times a$

$5 \times (-b) = 10 \times a$

$5 \times (-b) \geq 10 \times a$

$5 \times (-b) \approx 10 \times a$

5) Think of a fraction which is equivalent to 9/15, and the sum of its numerator and denominator is 120. What is the fraction?

V. RATIO OR PROPORTIONAL THINKING

1) What is the missing term in the proportion n:2 = 30:15?

2) A skydiver falls 144 ft in 3 seconds. How high does he fall in 0.5 minute?

3) There were 162 freshmen students who joined the thanksgiving parade. If this presents 23% of the freshmen class, how many freshmen were there?

4) If 25 liters of fuel can cover 0.14 miles, how far will 40 liters go?

5) If a machine can produce, 2550 metal parts in 7 ½ hours, how long would it take the machine to produce 4080 metal parts?

VI. PROBABILITY THINKING

1) Determine the probability that a tossed coin will land head?

2) If a number is chosen among the prime numbers less than 20, what is the probability that the chosen number is 19?

3) Choose a number from the following data, 0.12, 0.14, 0.15, 0.18, 0.2. What is the probability that the second number is chosen?

4) Choose one from a deck of 52-cards. Find the probability that a face is chosen. Express your answer in percent.

5) Under the best conditions, a wild bluebonnet seed has a 1/5 probability of growing. If you select two seeds at random, what is the probability that both will grow under the best conditions?

VII. CORRELATIONAL THINKING

Indicators: Correlation is a measure of the degree of association or strength of the relationship between two variables.

A. Two variables are having positive or direct correlation if these follow the same changes, either both variables increase or decrease.

B. Two variables are having negative or inverse correlation if as one variable increases, the other variable decreases.

C. Two variables are having zero correlation if there's no existence of relationship between them.

Tell the kind of correlation you would expect to exist between the following pairs of variables. Write only the letter on the space provided before each number.

_____ 1) Economic condition in a certain community and crime rate

_____ 2) Buying price and selling price of a commodity

_____ 3) Amount of profit share and the number of shareholders

_____ 4) Size of shoes and its unit price

_____ 5) The speed of an automobile and the fraction of time it runs