IJAMS
INTERNATIONAL JOURNAL OF ADVANCED MULTIDISCIPLINARY STUDIES
Volume II, Issue 8 August 2022, eISSN: 2799-0664

The Critical Thinking Skills in Mathematics of the First Year College Students: SPIDA Cognitive Theory

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Abstract — The challenges encountered by the students in dealing with Mathematics have to be addressed for them to appreciate the importance of Mathematics in their lives. To connect mathematical ideas to other areas of study or aspects of life, critical thinking skills is seen to have been a great factor. The learners who think critically are often successful in general Mathematics. This leads to the objective of the study to examine the factors that are effective for the development of the critical thinking skills of students. In particular, this study sought to answer the level of critical thinking skills of the students based on information and discovery, analysis, interpretation, reasoning, problem-solving/solution finding, self-regulation and reflection. Furthermore, it examined the relationship between the level of critical thinking skills and the scores of the students in General Mathematics. Using the descriptive – correlational method of research with regression analysis and theory development, it depicts the interrelatedness of the factors and significant relationship among the predetermined critical thinking variables to the scores of 50 first year college students in General Mathematics. Among the critical thinking skills variables, the Discovery and Information, Analysis, and Problem Solving/Solution Finding have strong and significant relationships with the General Mathematics score. And based on the findings, SPIDA Cognitive Theory was developed.

Keywords — critical thinking skill, mathematics education, mathematics performance, multi-regression analysis, theory development, descriptive-correlational, SPIDA cognitive theory

I. Introduction

One of the abilities that pupils are expected to learn is Mathematics. Many students, however, find Mathematics intimidating, difficult to comprehend, and much more difficult to master. Memory and concentration issues, trouble grasping mathematical ideas, linguistic obstacles in word problems, and computational weaknesses are among the issues that typical

Mathematics learners encounter. These challenges need to be addressed in order for the students to recognize its relevance and become more productive in the future.

Critical thinking has recently been designated as one of the learning and innovation abilities required to prepare learners for post-secondary education in the 21st century. Students who have mastered the formulas and meanings via repetition and rote memorization are often distinguished from those who can actually grasp what they are doing by the use of critical thinking. The edge of those who use their critical thinking is that they can conduct calculations and explain concepts when they are doing arithmetic or even higher Mathematics. The need to do data analysis, identify local trends, and decide on a strategy for forecasting or determining solutions to solve the problem, all require critical thinking skills. To make their forecasts, they might need to apply a range of formulas and statistical methods and teachers can go one step further by having students defend and explain the strategies they employed. Without the skill of critical thinking, students developed negative reactions towards Mathematics.

In today's age of technology, the critical thinking ability becomes urgently needed so that humans can deal with changes in circumstances or challenges that they are always facing (Ulfiana, et. al, 2019). As to the field of education, Rogovaya, et. al (2019) stated that critical thinking plays a significant function in education, as it is applicable in all facets of knowledge, as well as in day-to-day living. And as supported by Firdaus, et. al (2015), critical thinking skills should be part of student's learning and schools should be responsible to develop and evaluate critical thinking skills through teaching and learning process.

As to the Philippine setting, development of critical thinking among students is the goal of the Philippine Mathematics Education. As cited by Buan, et. al (2021), The DOST-SEI with MATHTED, Inc. published that the Philippine basic education mathematical framework is concentrated on the attainment of mathematical empowerment where the development of critical and analytical thinking at its core. As in their previous article of MATHTED in 2006, they had delivered that critical thinking encompasses the following components; first, problem solving, second, communicating and reasoning, and third, making mathematical connections. They believed that the learners who think critically are often successful in problem solving, in communicating mathematical ideas using the precise language of Mathematics, in making reasonable and logical statements, and in thinking of his/her own thinking in order to connect mathematical ideas to other areas of study or aspects of life.

Although many studies have recognized and supported the importance of critical thinking skills, there has been a gap as to what are the factors associated with it. The influences towards the ability to develop the critical thinking skill is seen to be inexplicit. Teachers have their own way of developing the said skill towards its learners but it must consider on which characteristics or areas that the teaching-learning process must focus for the critical thinking to be fully developed. That is why the researchers considered some variables out of several studies that have association to the critical thinking skills and to be tested on the respondents of this study.

The researchers had further observed that some of the students today were not that good in solving mathematics problems and not that motivated in learning Mathematics. The students were very passive during class discussions and activities but very active during breaks. The concern about the current performance and attitude of the students towards developing higher-order thinking skills stimulated the curiosity of the researchers to have this study. In this connection, this study sought to analyze the significant relationship between the level of critical thinking skills and the scores of the students in one of the subjects in Mathematics. This is to identify if the students are ready for higher mathematical education given their current level of critical thinking skills and the possible theory to be developed that will enhance the aforementioned skill.

As this study would be essential for theory development, it will be beneficial to all the educators and other recipients who are dealing with the development of critical thinking skills. The respondents of this study were the Bachelor of Secondary Education first year students majoring in Mathematics and enrolled in one of the local colleges in Davao Region. Moreover, this study would help the teachers develop their own strategies and techniques in dealing not only with the behavior of the learners but also in their attitude towards teaching and learning Mathematics.

II. Methodology

The research methodology contains the research method, research environment, research participants, research instrument, data gathering procedure, data analysis, and ethical considerations.

Method

This study utilized the descriptive – correlational method of research with regression analysis and theory development. According to Calmorin and Calmorin (2007), a descriptive correlational method was designed to determine the relationship of two variables (X and Y) whether the relationship is perfect, very high, high, marked or moderate, slight, or negligible.

This method was chosen since it was the most appropriate for answering the purpose of the study. This intends to get the significant relationship among the predetermined critical thinking variables. Moreover, this design would minimize biases and threats to the internal and construct validity of the study.

Environment

This study was conducted at Monkayo College of Arts, Science and Technology, Poblacion, Monkayo, Davao de Oro. The Monkayo College of Arts, Sciences and Technology (MONCAST) was the first LGU owned and operated local college in Compostela Valley to have been granted by the Commission on Higher Education (CHED) thru the regional office in Davao City, in accordance to the provisions of CHED Memorandum Circular Order (CMO) No. 40 series

of 2008 the permit to operate dated June 11, 2009. The programs offered were: Bachelor of Business Administration (BSBA) with majors in Marketing Management, Human Resource Development, and Financial Management; Bachelor of Elementary Education (BEED) Generalist; and, Bachelor of Secondary Education (BSED) with majors in English, Social Studies and Mathematics. MONCAST is also a member of the Association of Local Colleges and Universities (ALCU) in the Philippines and has also granted the Level 1 Status in most of its programs.

MONCAST was established under the administration of Mayor Manuel B. Brillantes Jr. through Municipal Ordinance No. 21 dated August 19, 2008 authored by then SB Member Remigio T. Saldua which gained unanimous support of the other local officials for the term 2007~2010. It envisions to become the leading local college in Davao Region, recognized for its affordable and quality instructions, responsive to the needs of people of Monkayo and its neighboring communities. Its mission is to provide quality and dynamic instruction, research and extension service, responsive to the needs of the community and proactive to the global trends. It has a total population of 2,861 students with 1,144 first year students.

Respondents

The respondents of this study were the first-year college students majoring in Mathematics of Monkayo College of Arts, Science and Technology. There were 50 selected first year students from 505 first year education students. Respondents of this study were determined through quota sampling.

The inclusion criteria for this study were; first, respondents must be bona fide students of the institution, and second, each of them must have consented to participate in the study regardless of their age and gender. If one of the criteria has not been complied the target respondents were automatically excluded to participate. These inclusion and exclusion criteria were for scientific merit and safety concerns, and to make sure that the participants were the appropriate target respondents for the attainment of the anticipated output of the study.

Sampling Technique

Quota sampling was used in this study. It is a form of non-probability sampling, a way of achieving sample size purposes and performed before a specific number of units chosen for many sub-populations with no guidelines as to precisely how these quotas should be completed (Iliyasu & Etikan, 2021). The respondents were chosen based on categories that represents characteristics of the population. The researchers targeted the quota of 50 respondents for this study.

Instruments

This study used a 10-item self-made questionnaire to determine the level of the critical thinking skills of the respondents. It was a short response test with no multiple choices. The respondents were instructed to write their solutions to each problem. The sources of the questions

came from the books; Philippine Mathematics Framework for Basic Education by MATHTED and DOST, General Mathematics Soaring 21st Century Mathematics by Chua et.al, and Teaching Guide for Senior High School General Mathematics by the Commission on Higher Education. The word problems involved critical thinking skills for Mathematics of investment, functions, and mathematical reasoning. The target competencies were; first, representing real-life situations using functions, including piecewise functions. Second, evaluating functions and solving problems involving functions. Third, solving problems involving rational equations and inequalities. Fourth, computing the interest, maturity value, and present value in simple and compound interest environments. Fifth, calculating the present value and period of deferral of a deferred annuity. Sixth, illustrating and solving problems involving stocks and bonds. Lastly, establishing the validity and real-life arguments using logical propositions, syllogisms, and fallacies. The questionnaire was validated by three Mathematics experts. They were master teachers in their respective schools. The researcher considered all of their comments for the revisions of the questionnaire. For the reliability testing, Cronbach's alpha coefficient was utilized to test the internal consistency reliability of the measuring instrument. This was given to the fifteen (15) fourth year high school students of Monkayo College of Arts, Science and Technology.

The value of Cronbach's Alpha is usually expressed as a number between .00 and 1.0. A value of .00 means no internal consistency while the increase in positive value of Cronbach's alpha above zero indicates that items are advancing to a stronger interrelationship. A value of 1.0 indicates perfect consistency in measurement. The acceptable range is between 0.70 and 0.90 or higher depending on the type of research. Cronbach's Alpha of 0.70 is acceptable for exploratory research while 0.80 and 0.90 are acceptable for basic research and applied scenarios respectively (Aithal & Aithal, 2020, Olaniyi, 2019).

Result shows that research instruments for Discovery and Information, Analysis, Interpretations, Reasoning, Problem Solving, Self-Regulation, and Reflection scales of measurement achieved a reliability of 0.840, 0.862, 0.835, 0.851, 0.830, 0.864, and 0.818 respectively. The internal consistencies are all interpreted as Good and indicated high reliability. The researchers could have increased the value to 0.9 and above by following Cronbach's alpha if the item is deleted. However, Sürücü and Maslakci (2020) stated that a high value between 0.95 to 1.0 indicates that some expressions found in the measuring instruments are the same and do not have any distinguishing characteristics. In other words, this signifies that there are more expressions in the measuring instrument than needed and that this behavior or quality can be measured with lesser expressions. And for this reliability test, the results are just as good as interpreted.

There is an excellent internal consistency in the scores of students in Mathematics as presented. To identify the levels of the critical thinking of the respondents, the researcher used a 35-item Likert scale with seven variables with respect to the characteristics of the cognitive skill. The critical thinking indicators were inspired from the rubrics made by the Catalina Foothills

School District, Tucson, Arizona. It was published last 2014 and updated last 2015. The rubrics were intended to support student progress in mastering the deep learning proficiencies. Four levels of performance were articulated in each rubric: Score 1.0 (Novice) describes student performance that demonstrates readiness skills for score 2 but requires significant support, score 2.0 (Basic) describes student performance that is approaching proficiency, score 3.0 (Proficient) describes student performance that is proficient in the targeted expectations for each performance area, and score 4.0 (Advanced) describes an exemplary performance that exceeds proficiency.

The above range was used to determine the level of the critical thinking of the respondents, with the corresponding descriptive rating and interpretation. It was determined through the help of the three raters who were master teachers from different schools.

Data Gathering Procedures

The researcher followed a step-by-step process before the gathering of data. The following had been observed; first, the researchers asked permission from the professor to start the data collection, second, asked permission from the president of Monkayo State College of Arts, Science and Technology for the gathering of data, and fifth, they personally asked permission and assistance from the Mathematics teacher of the school in the administration of the test.

The researcher asked help from them to facilitate the test in one-hour time using a conducive room to avoid copying and spreading of leakages, and to promote honesty among the respondents. Lastly, they asked permission from the target respondents. The researchers told them the purpose of the study and gave them proper instructions before answering the ten-item questionnaire. Each respondent was given 60 minutes to answer. After the respondents answered the questionnaires, the researchers tallied, analyzed, and interpreted the data.

Data Analysis

The following statistical tools were used in the computation of data in order to get the accurate result with 95% level of confidence: first is frequency. It was used to determine the number of correct responses of the respondents. The percentage was also solved after, it is a product of 100 and the ratio of the correct responses over the highest possible score. To determine the level of critical thinking skills the mean and weighted mean were used. Mean is the sum of the collection of results divided by the result of results in the collection while weighted mean is a kind of average that instead of each data point contributing equally to the final mean, some data points contribute more weight than others. Pearson's Product-Moment Correlation Coefficient (Pearson r) was used to determine the significant relationship among the predetermined variables of critical thinking skills. It is a measure of the linear correlation between two variables X and Y. It has a value between +1 and −1, where 1 is total positive linear correlation, 0 is no linear correlation, and −1 is total negative linear correlation. To predict the value of a single dependent variable by using known independent variables multiple regression analysis was utilized. It is a statistical method for examining the connection between numerous independent variables and a single dependent

variable. The weights of each predictor value indicate their respective contribution to the total forecast.

III. Results and Discussion

Results

The multicollinearity tests of the identified independent variables, the levels of critical thinking skills, and the relationship between the determined independent variables and the level of critical thinking skills are presented and interpreted to meet the objectives of this study.

The collinearity statistics, the Tolerance and VIF (Variance Inflation Factor) check the assumption of multicollinearity. As a rule of thumb if VIF >10 and tolerance <0.1 the assumptions have been greatly violated. In other words, the Multicollinearity Test's value for VIF should not be greater than 10 and the Tolerance should be .10 or greater for it to be significant and acceptable. (Goss-Sampson, 2020)

On the other hand, the levels of critical thinking skills of the respondents are also presented given the range of 1~1.75 as Novice, 1.76~2.5 as Basic, 2.6~3.25 as Proficient, and 3.26~4 as Advanced levels. While, the result of Pearson correlation at 5% level of significance with $0<r<0.2$ as veryweak, $0.2<r<0.4$ as weak,$0.4<r<0.6$ as moderately strong,$0.6<r<0.8$ as strong, ,$0.8<r<1$ as very strong and $r=1$ as perfect correlation.

The Tolerance value of the critical thinking indicators namely: Discovery and Information, Analysis, Interpretation, Reasoning, Problem Solving, Self-Regulation and Reflection are all ranging from 0.4 to 0.8 which are above 0.1. On the other hand, the Variance Inflation Factor (VIF) are all less than 10. It can be interpreted that the data of the mentioned indicators are all significant and acceptable.

The scores of the students in General Mathematics were taken and resulted in a mean of 7.56 with a minimum value of 5.00 and a maximum value of 9.00. The interpretation based on the result is Passed. The basis of passing score is the standard of the school where the study is conducted. It has a grading system with a base of 40. It further means that in a test item of 10, the passing score is 6.

The computed means and standard deviations are 3.08 and 0.66517 for Discovery and Information, 3.20 and 0.69985 for Analysis, 3.10 and 0.61445 for Interpretation, 3.00 and 0.60609 for Reasoning, 3.18 and 0.69076 for Problem-Solving, 2.72 and 0.68243 for Self-Regulation, and lastly 2.94 and 0.54995 for Reflection. All the data imply that the levels of critical thinking skills of the respondents are all proficient.

The predictors with strong and significant relationships with the dependent variable score are Discovery and Information, Analysis, and Problem Solving. Its correlation values with the dependent variable score are 0.690, 0.748, and 0.644 respectively. In academic research, r-squared

values of 0.75 is generally considered strong effect size and substantial, (Sarstedt, M., & Mooi, E. (2014,p.211)). R-squared is a goodness of fit measure for linear regression models. This statistic indicates the percentage of the variance in the dependent variable that the independent variables explain collectively. As presented in the table, the r-square value is 0.767 which can be described as substantial and strong to confidently determine which independent variables matter most in developing a theory. This value together with the overall correlation coefficient of 0.876 suggests a very strong positive correlation between the scores and the independent variables. From these results, we could develop a theory involving the three critical thinking independent variables that can predict good Mathematics scores. The developed theory will be a great help for students, educators, and other users for this will not only guide them in teaching and learning process but also improve higher-order thinking skills.

Discussion

Based on the results presented, all the critical thinking skill variables namely: information and discovery, analysis, interpretation, reasoning, problem-solving/solution finding, self-regulation and reflection are significant and acceptable to be utilized in the multi-regression analysis. While, the scores of the students in General Mathematics are all passed. And among the critical thinking skills variables, the Discovery and Information, Analysis, and Problem Solving/Solution Finding have strong and significant relationships with the General Mathematics score. From these findings, the following propositions were made to develop a theory:

IV. Propositions

Discovery and Information

Proposition 1: Learning Mathematics by discovery is an effective stimulation to make Mathematics interesting as it promotes originality.

Rochani (2019) as cited by Rihayati, et. al (2021) explained that discovery learning is a series of undertakings that are expected to empower learners to become self-regulating individuals who are able to develop their cognitive skills. And according to several studies, when students view the acquisition of information as a process, their problem-solving skills are developed that have been found to have a good effect on the learner's performance (McCollister & Sayler, 2010; Tsai, et. al, 2013; Nappi, 2018).

Proposition 2: Students can create meaningful comparisons in General Mathematics.

Analysis, as considered as self-thought-life skill, is associated with critical thinking, gathering and processing of information, and visualization that our brain receives (Lamiya, 2022).

Solution-Finding and Problem-Solving

Proposition 3: Students identify the amount of intelligence would lie measured by the degree of difficulty of tasks completed of their complexity.

Problem solving skills, as the ability to combine information from various sources and to identify relevant data to become appropriate in finding solutions is seen to be one of the competencies of critical thinking (Fitarahmawati & Suhartini, 2020).

SPIDA COGNITIVE THEORY

As the study progressed, the researchers found out that the three variables under critical thinking namely Solution-Finding or Problem Solving, Information and Discovery, and Analysis (SPIDA) were strong predictors of good scores in Mathematics. Good scores in Mathematics would imply having a deep understanding of how and why things work. It has been linked to good well-being, life satisfaction, health, income, employability, and lifespan, (Lipnevich et al., 2016).

The birth of the SPIDA Cognitive Theory was introduced to predict scores in Mathematics and level of critical thinking skills of students. The term SPIDA was derived from the word spider with interconnected webs. The three variables worked together to solve practical problems and promote critical thinking abilities. The educators and curriculum designers can use it in forecasting students' performance and improving the curriculum.

In connection to the propositions, the student with a proficient level of critical thinking can learn Mathematics by discovery, can create meaningful comparisons (analysis), and can identify multiple, innovative, plausible solutions to the problem (solution-finding or problem-solving). Discovery is an effective stimulation to make Mathematics interesting as it promotes originality. Hanum (2018) wrote, "Learning activities using discovery method (discovery) is actually similar to inquiry (inquiry). While discovery is the process of discovering concepts through a succession of data or information collected through observation or experimentation, inquiry is the process of answering questions and addressing issues based on facts and observations (p. 4).

Discovery and information skills generate thought provoking inquiry questions, and value information obtained through the investigation. Analysis involves estimating specific mathematical ideas, such as numbers or functions, by other, more comprehensible objects (Qolfathiriyus, A., Sujadi, I., Indriati1, D., 2019). It is crucial for situational understanding, fact-checking, and fact-deconstruction skills. It is evaluating the sources of information, the accuracy and relevance to the problem. On the other hand, problem-solving gives students the opportunity to practice using their mathematical understanding and expertise to address everyday situations. Word problem solving is one of the important components of mathematical problem-solving that incorporates real-life problems and applications (Azizah, Rohani, & Mokhtar, 2010). It employs pertinent standards to weed out unworkable options and pick the most logical ones. Puts selected alternatives through trials to determine the utility in solving.

Discourse-specific practices control how we interact with Mathematical things in general and how we tell stories about Mathematics in particular. These comparatively stable patterns of action reflect on human propensity for repetition: whenever people find themselves in a situation where they feel the need to act (referred to as a task situation), they typically recapitulate what was done in similar circumstances in the past that they believe make such repetitions appropriate (Mazana, Suero Montero, & Olifage, 2019).

Those who support teaching, teachers themselves, students, and those involved in professional education and professional development will all find Critical Thinking: An Exploration of Theory and Practice interesting. This method of identifying and enhancing students' critical thinking abilities will be helpful to teachers in all subject areas at higher and further education levels in school (Moon, 2007).

Anchored in the conclusion that stated to produce students who think critically while addressing a problem, the use of critical thinking abilities in Mathematics disciplines can also help students retain what they are learning. This demonstrates the Critical Thinking Skills aspect acts as a stimulus for pupils to grasp the material, which in turn improves Mathematics proficiency (Ismail, Muhammad, Kanesan, A. & Ali, 2019).

Inspired to one of the newest theories for intricately planning and organizing the content is Reigeluth Theory, which is based on a progression from basic to complex and from general to specific issues in learning concepts, generalizations, skills, and principles, as well as cognitive details and connections between the course's internal and external relationships (Elsayed, 2015).

Therefore, Critical Thinking Skills was an effective means of enhancing students' understanding of Mathematics concepts because the skills have helped in interpreting, analyzing, evaluating, and presenting data in a logical and sequence manner.

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