



Cognitive Levels towards Performance of Mathematics Score in Secondary School

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ABSTRACT

Cognitive is relating to cognition. It refers to the method by which knowledge is acquired and manipulated. Usually, cognition is mental. The mental processes associated with phenomena such as concentration, logic, thought and evocation. Generally, characterized as reflects the mind. It is not observable directly, but it must be inferred. Malaysian educators trying so hard to make sure all students master or at least having good knowledge in Mathematics. Investigation on cognitive levels towards performance of Mathematics score among secondary school's students is the main purpose of the study. A secondary data was used for the process of investigation. A total of 118 secondary school's students in Tapah were involved randomly. The analyses were started using multiple linear regression with the aid of IBM SPSS version 24. Results show that cognitive levels significantly affect the performance of Mathematics score. These cognitive levels include Knowledge (C1), Comprehension (C2), Proficient (C3), Synthesis (C5), and Analysis (C6). Among five levels of cognitive, results show that Comprehension (C2) or in other words understanding of facts and ideas give the highest impact towards the performance of Mathematics score. If the students do not understand well in topics covered from Mathematics, they will not perform well in Mathematics. In this situation, both teachers and students play an important role to make better results in Mathematics.

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1. Introduction

The development country can be seen through their technology and science achievement. Changes in the development of science and technology makes people try to adapt with the situation. In the process of adoption, some education enables individuals' creativity, reasoning and problem-solving skills that give an important role to make the process successful. One of the education that can make the development of science and technology go to a higher level is Mathematics. In Mathematics, people were able to get use of rules or formulas, perform arithmetic operations, have a higher level of thinking and become a good problem solver. All these characteristics are based on mathematical features [1]. In Malaysia, education of Mathematics had been started since kindergarten until tertiary level of education. In fact, Malaysian learn Mathematics everywhere and anywhere. For example, buying groceries at market, solving financial problems of a company,



managing the construction of building a shop lots and many more. All these activities involve concept, theory, and knowledge of Mathematics. Kitab Hisab was the first mathematics textbook written by Durell which includes logic, algebra, and geometry [2].

Malaysian educators trying so hard to make sure all students master or at least having good knowledge in Mathematics. Topics to be covered in Mathematics were from low level to high level of difficulties. In that case, Malaysian used Bloom's Taxonomy level to measure the achievement of students in Mathematics [3]. Benjamin Bloom is the creator of the Bloom's Taxonomy in 1956 which consists of three learning activities. The first category focus on mental skills or knowledge namely 'Cognitive', 'Effective' that focus on attitude and emotional areas or feelings on specific growth in feelings or emotional areas and attitude. Last was focuses on manual or physical capabilities that is 'Psychomotor' [3].

This study only focuses on the 'Cognitive' level that comprises six areas. The first area is 'Knowledge' (C1) which enables students to extract any facts or information from their long-term memory. 'Comprehension' (C2) refers to understanding demonstration using rationalization. Next, 'Proficient' (C3) is implementing or executing procedure. 'Evaluation' (C4) focus on breaking material into a component of elements to investigate how they are related to each other. Then, 'Synthesis' (C5) is to make judgments based on characteristics and standards. Lastly, 'Analysis' (C6) which means to put parts along to generate a replacement coherent or a useful whole; reorganizing elements into a new pattern or structure [3]. For countries like Malaysia, secondary school is classified into lower and upper classes having three and two periods of years respectively. Students will sit for a summative assessment namely Form Three Assessment (PT3) to assess the academic achievement of students at the lower secondary level. The results on this assessment will be used to make the students able to choose the suitable combination of subjects for the first year of upper secondary school. In the last year of upper secondary, students sit for Sijil Pelajaran Malaysia (SPM), Malaysian Certificate of Education, which is equivalent to the British Ordinary or O Levels [4].

The crucial part that concerned calculations and problem-solving is ability on using Mathematics. Typically, this subject unremarkably been recognized as killer subject or most tough subject to be comprehend. Once believe that mathematics is a subject that characterize with many difficult formula, facts, concepts rules and many more. Supported to these consequences, students get difficulty to perform in mathematics especially solving it. As a result, psychological feature skills from Bloom's Taxonomy were introduced to assist them with their mathematics difficulties. Cognitive abilities are developed from a theoretical standpoint to high-level thinking, and that they are often applied altogether in educational systems. There are reasons why the students do not perform well within the examination although the cognitive level has existed within the education system. During the grade school level, the students have difficulty in understanding probability and statistical concepts since less or no curriculum instruction given. The lack of a concerted effort within the provision of cognitive skills by educators in mathematics subjects are going to be the matter. Thus, learning cognitive abilities for students should be observed. Furthermore, thinking flexibility, applying in students' prior knowledge, and remaining hospitable continuous learning should be observed by the educators because they are conversant in the concepts on mathematics. The complex idea in science can only be understood if more fundamental concepts involved within the formation of a replacement concept that are fully understood.

This study allows us to spot which of the cognitive level give the most affecting mathematic performance of secondary schools and which levels mostly contribute to the performance. Once the power of the student been recognized, it hopes that educators can find alternatives or solutions to extend the cognitive level of the students towards mathematic performance. So, this research is assumed to assist the teachers or educators to know their student's abilities during a mathematical subject. Ultimately, they might be ready to make an idea in formulating actual questions that suit their student's level of ability.

2. Literature Review

2.1 Relationship between cognitive levels and academic

The relationship between cognitive levels and academic performance are strongly related to each other. Students should be able to master all of the cognitive levels by Bloom's Taxonomy in order to perform well in academics. However, it is said that critical thinking such as analysis and evaluation alone cannot guarantee success in school. Students also must be prepared to use what they had learned in school and apply them in their learning. [5] found that critical thinking skills overlapped with general cognitive ability in predicting academic performance. In order for a student

to think and answer a question, they tend to use their knowledge, comprehension, analysis, synthesis, evaluation and application though it is not one hundred percent guaranteed their answer is true. However, it helps them in the processes of thinking and answering questions. This has also been supported by [6] which highlights that the academic performance of a child who has a higher cognitive ability is likely higher than a child who has a lower cognitive ability. Thus, it strengthens our findings that cognitive level does affect the academic performance of a student. Consequences of that, this study attempts to discover the cognitive level of mathematical subjects among secondary school students in Tapah.

Regression analysis had been used to predict the effect of item's type and cognitive level on its difficulty effect by using the sample of TIMSS (Trends in International Mathematics and Science Study) [7]. It is found that the cognitive levels contribute to the model by 3%. This study also predicting the β coefficients to identify the positive or negative relationship for the cognitive level.

One study has investigated the different of cognitive patterns and complex relations between cognitive variables, motivation and background variables associated with different levels of mathematical performance. The researchers use artificial neural networks (ANNs) and found that differences in the pattern of relative predictive weight amongst those variables. They also highlighted the impact on educational quality improvement and accountability [8]. Other than that, a research had been conducted by using a method of Piaget's Test of Logical Operations and Van Hiele's Levels of Thinking. to prove the importance of deductive thinking and transitivity in learning the Geometry and Mathematics. This factor was fall under cognitive levels [9].

Individual's understanding and deciding the right strategy on solving mathematics problems were affected by cognitive levels. Based on the analysis, it revealed that when students with low ability skill in solving mathematics faced difficulty in solving mathematics like defining equations, inequalities, similarities, and dissimilarity; they have not been able to distinguish between linear and non-linear correctly, and they have not been able to write or search for hidden information in the question. This study using time triangulation technique for checking the validity of data. Time triangulation is comparing and re-examining the degree of trust in information obtained through different times. The data analysis technique is Miles and Huberman techniques, namely data reduction, data presentation, and conclusions or verification. Data analysis is carried out by analyzing the results of task-based interviews about three-variable linear equation system. [10]

Besides that, the importance of understanding had been proved useful in determine the excellence in mathematics. By using the multiple linear regression analysis, the study found that English proficiency predicted English language learners (ELLs) mathematics scores and that grade level moderated the influence of English proficiency in predicting those mathematics scores. The study supports the notion that ELL students who read well perform better on mathematics assessments than those ELLs who do not [11].

2.2 Relating Cognitive Domain with Academic Performance

Academic performance has the most important role in education. It is believed that indirectly will affect students' future career. Nowadays, the first thing that employers will look into is how well the education level of the applicant is. The way you learn is the way that can help you to perform well in your studies. One of the most important factors that is often emphasized is cognitive level of learning. By definition, the cognitive level defined by the Merriam-Webster dictionary is relating to, being, or involving conscious intellectual activity such as thinking, reasoning, or remembering. Cognitive skills and knowledge involve the ability to acquire factual information, often the kind of knowledge that can easily be tested. The cognitive level can be related to Bloom's Taxonomy specified in six levels of cognitive levels which are knowledge, comprehension, application, synthesis, and evaluation. All these six cognitive levels are related to academic performance.

The first cognitive level that we could practice is Knowledge (C1). According to [12] knowledge is information that has been organized by a person or can be defined as actionable information. As [12] also stated that the way a person organized the information that he gets is based on the learning style that they used. Information and knowledge are two different things. Everyone can get knowledge; how do you gain knowledge is the thing. In order to become a perfect learner, everyone should know how to gain knowledge with adapting to any situation given. Knowledge sharing is also one of the ways to gain new knowledge. [13] highlighted the best way to have power knowledge is by sharing your knowledge with other persons. How knowledge is related to academic performance? When you have enough knowledge, it means you understand what you have learned from your lecturers or teachers. Then, it would help you in your exam or any task, so you will strive for excellence in your academic performance.

Next is Comprehension (C2). It is the second level of cognitive that shows your understanding of facts and ideas that you learn by organizing, comparing, translating, interpreting, paraphrasing, and stating main ideas. [14] shows that remembering is only focusing on what you want to remember but understanding is more than critical thinking about something. Two types of text that you can comprehend are known as narrative texts or expository texts [15]. [15] state that reading narrative texts are much easier to comprehend than reading expository texts because it describes a character's experiences, predictable events that are stated in sequence and use simple vocabulary which is easy to understand. When you are understanding well what you have read, you can easily evaluate the point that you understand by using your own words. An example of questions that may be asked to you is; how do you explain the situation that you read? Or what is your idea about the topic? When you are asked those questions, you can generate ideas by using your own words to answer them.

The third cognitive level is Proficient (C3). It has been used to apply what you have learned to the real-life situation. [16] stated that students can use the knowledge, facts, and techniques that they have and apply it to any situation to solve the problem. For this cognitive level, students must have critical thinking skills because they need to apply what they have learned to the problem that they should solve. According to [5], students need to practice developing critical thinking skills because it would help them a lot for your academic success.

Next is the cognitive level that has been classified into higher order [17] in cognitive level which is Evaluation (C4). The example of evaluation process is when someone wants to reflect upon something and uses the feedback or results to judge the value of it. Thus, it is called evaluation. It is important to judge something to find its value in order to make a certain decision. Values and criteria are an essential conversation as it sets out the decision in deciding important things that need to be found. According to [18], evaluation is a pop-up profession in a similar situation with different sectors defining evaluation distinctively based on their point of view. In order to make an evaluation, one must have to apply the logic in that particular evaluation.

Next two higher cognitive levels are Synthesis (C5) and Analysis (C6). Synthesis is something that happens naturally in everyday life. It happens not just in a conversation, but also online, at home and also at work. The written synthesis should show where the sources converge and also diverge. [19] synthesis is quite similar to but not exactly the same with categorizing or relation. There are keys in writing synthesis which are to understand and read well on the main points and the composition of the sources. The things that should be able to be seen during synthesizing are seeing the agreements, arguments and the explanation in the context. While for Analysis, it is said that analysis is when you are distinguishing between facts and beliefs and identifying the assertions upon which the difference of opinion is built [16]. Analyzing is crucial for the students in the process of understanding what they are reading. If the students are unable to understand what they are reading, they will have difficulties to interpret and thus the information from reading is no longer relevant. It is believed that a reader is able to make a thorough analysis when the materials that they read caught their interest. It makes them want to read more since they understand the flow, the process and the meaning of the writing.

3. Research Method

A secondary data was used for the process of investigating the cognitive levels towards performance of Mathematics score. The data consist of 118 randomly selected secondary school's students in Tapah. All the information taken from the sample were gather and used for the purpose of this investigation. The investigation was started using multiple linear regression with the aid of IBM SPSS version 24. Refer Figure 1 for the illustration of the theoretical framework.



Figure 1: Theoretical framework (Adapted from [3].)

The investigation for more than one independent variable with the dependent variables are often done using multiple linear regression [7]. In this investigation, performance of students in Mathematics score is the dependent variable while C1, C2, C3, C5 and C6 are the independent variables (Figure 1). The independent variables which refer to the cognitive levels had been develop by using a set of 50 mathematics questions with the cooperation of school teachers. The cognitive levels were measured using a set of questions that resulting a score. By using the score, the required cognitive levels will be identified [3]. Hypothesis for the analysis are as follow:

- H₀: C1, C2, C3, C5 and C6 are not affecting performance of students in Mathematics score.
H₁: C1, C2, C3, C5 and C6 are affecting performance of students in Mathematics score.

Rejected H₀ if p-value ≤ significance value (α) = 0.05. If this happens, it shows that the variable(s) is/are significantly affects performance of students in Mathematics score. The multiple linear regression model are as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon \tag{1}$$

where Y is the dependent variable, X₁, X₂, ..., X_n are the independent variables, ε is the residual term while the β's are the regression coefficients with β₀ is the constant term. In order to use the multiple linear regression analysis (1), some assumptions have to be met. The assumptions are that the values of the residuals have to be normally distributed, independent, no multicollinearity exists, and no outlier exists in the dependent variable.

4. Results and Discussion

4.1 Testing the significant of the model

Table 1 shows results for testing the significance of multiple linear regression models. The results of multiple linear regression models are valid and statistically significant. (F(5,112) = 635.306 p-value ≤ 0.05).

Table 1. Significance of the model

Source of variation	Sum of squares	Degrees of freedom (df)	Mean Square	F-value	P-value
Regression	2.544	5	0.509	635.306	0.000
Residual	0.090	112	0.001		
Total	2.634	117			

4.2 Coefficient of determination

In consequence of the standard regression analysis, the model's degree of predicting the dependent variable was found to be R = 0.966. The model's degree of explaining the variance in the dependent variable was R² = 0.964. Besides, 96.4% of the adjusted R² indicates higher and better in fitting the model (Table 2).

Table 2. Summary of the model

R	R Square	Adjusted R Square	Standard error of estimate	Durbin Watson
0.983	0.966	0.964	0.0283	0.672

4.3 Diagnostic Checking

4.3.1 Results of normality test of the residuals

Refer Figure 2 for the results of normality of residual.

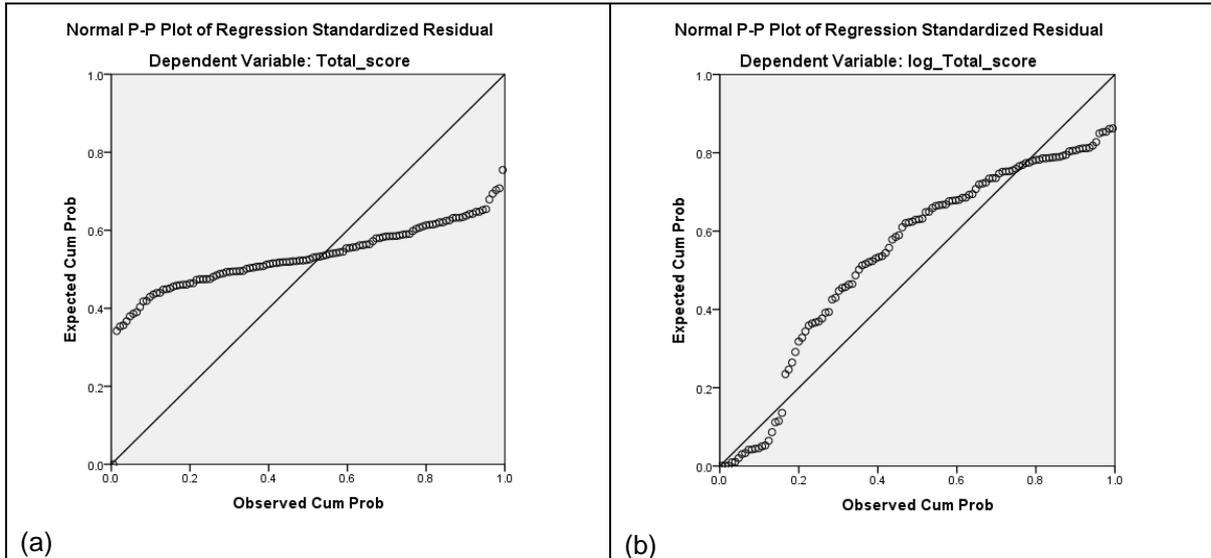


Figure 2: P-P plot for the normality of residual

The assumption of normality of the residuals can be tested using P-P plot for the model. Normality can be detected if the dots of the residuals lie closer to the diagonal line. In this investigation, the first plotting of the P-P plot of the residuals shows normality is violated (Figure 2 (a)). In order to overcome the problem, transformation of the dependent variable of total score has to be done. The transformation was using logarithm base 10 of the dependent variable. After plotting the P-P plot of the residuals, the assumption of the normality for the residuals is not violated. All the dots of residuals lie closer to the diagonal line (Figure 2 (b)).

4.3.2 Independent of the residuals test result

Assumptions of independent or uncorrelated for residuals can be checked using Durbin-Watson test statistics. If the value lies between 1 and 3, it shows the assumptions are not violated. In this investigation, the value of Durbin-Watson test statistics was 0.672. With that, the assumption of independence can be accepted (Refer Table 2).

4.3.3 Multicollinearity test result

Table 3 shows the collinearity statistics that will detect the existence of multicollinearity. If multicollinearity exists, the results of Tolerance and VIF are below 0.2 and above 10 respectively. Multiple linear regression does not allow multicollinearity problems to exist. If the intercorrelations among two or more independent variables are high, multicollinearity may exist. Multicollinearity may produce wider confidence interval that can result in less reliable of probabilities in terms of the effect. From the results, multicollinearity does not exist since all Tolerance values are above 0.2 and all VIF values below 10.

Table 3: Collinearity statistics

Variables	Collinearity Statistics	
	Tolerance	VIF
C1	0.578	1.730
C2	0.586	1.705
C3	0.743	1.346
C5	0.721	1.387
C6	0.924	1.082

4.3.4 The existence of outliers

Cook's Distance can be used to check whether outliers exist in the model or not. Outliers may influence results of the model. It may be not reliable if the existence of outliers is high. Therefore, any outlier should be removed from the data. Any values over 1 are likely to be significant for outliers to exist. Table 4 shows Cook's Distance values are all under 1 with the minimum value 0 and maximum value 0.201. This indicates that no such outliers have occurred.

Table 4: Residuals statistics

Cook's Distance	Statistics
Minimum	0.000
Maximum	0.201
Mean	0.010
Standard deviation	0.023
N	118

4.4 Regression Coefficient Testing

Table 5 shows that all variables Knowledge ($t = 0.020$; $p\text{-value} \leq 0.05$), Comprehension ($t = 0.021$; $p\text{-value} \leq 0.05$), Proficient ($t = 0.023$; $p\text{-value} \leq 0.05$), Synthesis ($t = 0.019$; $p\text{-value} \leq 0.05$), and Analysis ($t = 0.020$; $p\text{-value} \leq 0.05$), are significant. Thus, we have enough evidence to conclude that all the cognitive levels give impact to the performance of Mathematics score.

The most contributed cognitive levels to predict academic performance is Understanding (Beta = 0.346) followed by Knowledge (Beta = 0.329), Proficient (Beta = 0.270), Synthesis (Beta = 0.261), and Analysis (Beta = 0.188).

Table 5: Regression analysis results

Model	Unstandardized Coefficients B	Std Error	Standardized Coefficients Beta	t	p-value
β_0	1.158	0.009		135.685	0.000**
X_1	0.020	0.001	0.329	14.360	0.000**
X_2	0.021	0.001	0.346	15.216	0.000**
X_3	0.023	0.002	0.270	13.353	0.000**
X_4	0.019	0.002	0.261	12.719	0.000**
X_5	0.020	0.002	0.188	10.391	0.000**

Note: ** $p\text{-value} \leq 0.05$

Therefore, the estimated predicted model for predicting academic performance is

$$\hat{Y} = 1.158 + 0.020X_1 + 0.021X_2 + 0.023X_3 + 0.019X_4 + 0.020X_5 \quad (2)$$

By referring to (2), for each additional increase of Knowledge (X_1), the performance in Mathematics score increases by 0.020 with the other independent variables held constant. The 0.021 associated with the performance in Mathematics score indicates that for each additional increase in Comprehension (X_2), the performance in Mathematics score will increase 0.021, if the other independent variables held constant. Next, for each additional increase in Proficient (X_3), the performance in Mathematics also increases by 0.023 with the other independent variables constant. Then, each additional increase in Synthesis (X_4), the performance in Mathematics also increases by

0.019 with the other independent variables constant. Lastly, each additional increase in Analysis (X_5), the performance in Mathematics also increases by 0.020 with the other independent variables constant.

5. Conclusion

The cognitive levels towards performance of Mathematics score in secondary school is mainly focused on investigating whether cognitive levels affect the Mathematics score of secondary school's students or not. By performing the multiple linear regression, results show cognitive levels variables significantly affecting the performance of Mathematics score. These cognitive levels include Knowledge (C_1), Comprehension (C_2), Proficient (C_3), Synthesis (C_5), and Analysis (C_6). Among these, five levels of cognitive, results show that Comprehension (C_2) or in other words understanding of facts and ideas give the highest impact towards the performance of Mathematics score. If the students do not understand well in topics covered from Mathematics, they will not perform well in Mathematics. In this situation, both teachers and students play an important role to make better results in Mathematics.

Cognitive levels were divided into six levels but in this investigation levels number four was not included that is Analysing (C_4) and this results in the limitation of the investigation. Besides that, the 118 secondary students were taken randomly from Tapah, Perak area. This is probably the second limitation of the investigation.

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