AN INFERENTIAL STUDY ON ONLINE LEARNING DURING COVID-19 IN CALCULUS THROUGH CONCEPTUAL KNOWLEDGE

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ABSTRACT

Students should have a high level of conceptual knowledge in mathematics, especially when learning through online learning. Conceptual knowledge includes the creation of ideas that aim to help students understand the concept of mathematics better and play an important role in raising and deepening awareness of learning methods for students. Conceptual knowledge allows students to distinguish from a given question, insert symbols, and produce examples. This paper aims to investigate the impact of conceptual knowledge on student achievement in calculus taught through online learning. A statistical model of student performance in calculus using the regression method is developed, which considering students' attitudes towards calculus learning through online learning, the availability of support for online learning and infrastructure facilities for online learning as the variables. The data were collected from a group of students in a Higher Institution Education at Malaysia and questionnaire are used as an instrument of the study. The questionnaire is adapted from literature and been divided into five parts, which are demographic, perception of conceptual knowledge, students' attitude toward learning Calculus through online learning, availability of support toward online learning and accessibility of infrastructure toward online learning. Then, the students' final examination grades are used as a measure of student performance. The model developed shows a promising model to be used to predict the students' performance through conceptual knowledge, which can be used as a guide for all parties such as teachers, ministries, and education planners to guide in making education more effective in improving student mathematics performance specifically for the Higher Institution Education.

Key words: Conceptual Knowledge, Online Learning, Students' Performance, Regression

INTRODUCTION

Coronavirus disease (COVID-19) is an infectious disease caused by a recently discovered coronavirus (WHO, 2020). It may also cause various symptoms, ranging from a common cold to pneumonia (severe pneumonia). When a person infected with COVID-19 coughs or sneezes, the virus spreads by droplets from the nose or mouth. The epidemic was reported in Wuhan City, Hubei, China, in mid-December 2019. On 11 March 2020, the World Health Organization (WHO) recognised the disease as a pandemic (WHO, 2020). The COVID-19 pandemic has affected the education system either at the primary, secondary school, or Institutions of Higher Learning (IPT). Previously, the education system used conventional methods or 'chalk and talk', then switched to 'web-based learning'. Still, now new norms have changed the education sector of this country towards the use of technology as a whole. As a result, the current way of teaching and learning is to use entirely online learning methods. This new norm challenges the teaching staff to impart knowledge and the students' acceptance to receive the ability when taught online.

Online learning is defined as a tool that can make learning focused on student-centred, flexible and innovative (Dhawan, 2020). For that, students need to be creatived in processing the knowledge received. Traditionally, the students could discuss in groups or also known as cooperative learning. Hong Kong students began learning at home via interactive apps to try to curb the virus' spread. Through live television broadcasts, 120 million Chinese people were able to receive educational information (Weforum, 2021). Around the world, other, more straightforward methods were implemented. For example, to assist prevent school closures at one Nigerian school, traditional asynchronous online learning methods (such as reading material via Google Classroom) were supplemented with synchronous face-to-face video instruction (Weforum, 2021). Logically, students and educators will genuinely embrace the learning anywhere, anytime notion of digital education in various formats as it is known that 5G technology becomes more ubiquitous in nations such as China, the United States, and Japan. Traditional classroom learning will be supplemented by new learning modalities such as live broadcasts, educational influencers, and virtual reality experiences. Learning might become ingrained in people's daily habits like a true lifestyle.

Therefore, students need to apply conceptual knowledge in the process of acquiring knowledge through online learning. In general, in the research of mathematics education and mathematical thinking, lecture or students who able to develop conceptual skills is very lucky in helping them solving mathematical problems (Crooks & Alibali, 2014). Hiebert and Leferve (1986) define conceptual knowledge as full of information relationships and can be used and accessed flexibly. Students with these conceptual skills can identify relationships, distinguish symbols, apply mathematical theory, distinguish and integrate concepts and rules, and make assumptions and relationships involving mathematical concepts (Baker & Czarnocha, 2002).

At the higher-level education, one of the essential subjects is Engineering Mathematics which engineering students' study. Calculus is a crucial field of mathematics for their research. Studying calculus is an initial step for students to understand the real-life problems of science and engineering that have arisen from mathematics (Yaman, 2019). Based on authors experience, most students cannot accomplish a profound understanding and discover that calculus is difficult to understand and master. In particular, students face problems with the abstract concepts of rate of change, tangent, function, and limit (White & Mitchelmore, 1996). Students who have experienced learning beginner calculus in high school might feel it was difficult to understand the concept to

solve a calculus problem. They are then more likely to perform ineffectively and drop out of the calculus lesson (Mokhtar, Tarmizi, Ayub, & Nawawi, M, D, 2013). Many of them also give a reason that they did not learn Additional Mathematics in high school. Therefore, students must be good at conceptual knowledge besides acquiring problem-solving and communication skills to solve this situation.

Some previous researchers had studied conceptual knowledge. Studies conducted have found that a jigsaw co-operative learning strategy integrated with GeoGebra (JCLGS) increases the comprehension of calculus concepts and knowledge students (Yimer & Feza, 2019). Yurniwati and Yarmi (2020) conducted the latest study on conceptual knowledge prove that the online learning method effectively develops students' conceptual knowledge. The study conducted by Demuyakor (2020) found students are satisfied with online learning, and it is a good idea to incorporate online learning because most students have embraced this method due to lockdown.

Aside from that, several studies have been carried out to determine the important factors that influence students' performance as following mentioned. Most researchers point out that one factor considered a significant contributor to students' performance in Calculus is their attitude (Mazana, Montero, & Casmir, 2018). Martin, Stamper, and Flowers (2020) reported that online student attitude, learning time management, technical skills competence, and communication efficiency between students and lecturers at the point of emphasis. Chung, Subramaniam, and Dass (2020) presented in their paper stated that supports toward online learning also necessary and pre-recorded lectures uploaded to Google Classroom, and YouTube was favoured by most students. In a previous study, Kandemir and Demirbağ-Keskin (2019) reported that the use of technical instruments in teaching and learning is essential because most students are now exposed to different technology in their everyday lives for a few days.

Based on the literature above mentioned, generally, it is even more challenging because the lessons are entirely online. Logically, to ensure that constructive learning can be applied, students must mentally and physically prepare themselves. A primary aim of students should be to develop conceptual knowledge of mathematics. This is to offer mathematics sense by requiring students to know how to apply skills and expertise and when and how to do so. Some important factors that should be considered, mainly when conducting online learning, must be contemplated to succeed in such learning. Hence, in this paper, we focus on studying the effect of conceptual knowledge on student achievement in calculus taught through online learning and considering the significant factors which might influence the students' performance.

METHOD

Study Design and Sample

The study was conducted in one of the Higher Institution Education in Malaysia from August 2020 to March 2021 among students who were majoring in Engineering and take Calculus subject in the current semester. The study only focuses on conceptual knowledge perspectives through online learning and significant variables that improve their performance in the Calculus course. Using stratified random sampling, a sample of 146 students was selected.

Questionnaire

Data were collected using an online self-reported questionnaire. There are five sections in the questionnaire. Data on demographic respondent such as gender, race, a background of the majoring study, experience learning Calculus (Additional Mathematics) in high school, the device used to access online learning, type of internet connection and grade for Calculus subject in last semester were obtained in the first section. Perception of conceptual knowledge through online learning was assessed in the second section of the questionnaire (10 items). The third part of the questionnaire evaluated the students' attitude toward learning calculus through online learning (10 items). The fourth part of the questionnaire assessed the availability of support toward online learning (7 items), while the accessibility of infrastructure toward online learning was obtained in the last section. A result of the students' final examination grade provided data on the students' performance in calculus. A 7-point Likert scale (very strongly disagree, strongly disagree, disagree, neutral, agree, strongly agree, and very strongly agree) was used to assess all the 34 items in the questionnaire.

Statistical Analysis

The data were analysed using IBM Statistical Package for the Social Sciences (SPSS) version 26. A descriptive analysis and a normality test were performed as part of the preliminary analysis. To determine the significant factors that influence students' performance, the researchers used multiple linear regression analysis. The general known model is given by:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon$$

where

y : The pointer,

x_1 : Conceptual Knowledge through online learning,

x_2 : Students Attitude toward Learning Calculus,

x_3 : Availability of Support,

x_4 : Accessibility of Infrastructure,

and ε is a random error, and the regression coefficient is denoted by β's. The SPSS computer programme is used to analyse the data. In this study, we use a 5% level of significance. Identifying which independent variables contribute significantly to explain the variability in the dependent variable is a common goal in multiple regression. Hence, in this study, the stepwise regression includes the forward selection method, and the backward elimination method is used to choose the most appropriate model for multiple linear regression.

The forward selection method is a stepwise regression approach that increases r^2 the value by adding one independent variable at a time. It is beginning with a model that is devoid of variables (called the Null Model). Then, one by one, start adding the most important variables and continue to add the most significant variable before you hit the stopping rule or run out of options. A backward selection method, whereas all independent variables are included in the model at the start, and subsequent variables are removed. It begins with a model that provides for all the variables to be considered (called the Full Model). Then, one by one, the least important variables are removed.

RESULT AND DISCUSSION

Descriptive Analysis

A total of 151 respondents received the questionnaire. Only 146 respondents completed the requirements due to their inability to contact them and their refusal to participate in the study. As a result, the response rate for this study was 97%. In the data, there were no missing values. The frequency analysis shown in Table 1 indicates the frequency and percentage for each categorical variable in this study. Of the 146 respondents, most of the respondents (68.5%) are male. Most of the respondents (92.5%) are Malay, and most of them are students from the Department of Electronic Engineering (52.7%). More than half of respondents (58.9%) indicated that they have experience learn calculus in high school. One-hundred and four respondents (71.2%) reported that they used a laptop or notebook as a device for online learning and more than half of the respondents (65.8%) used mobile data as a type of internet connection. As a result of online learning, fifty-one respondents (34.9%) get an A for their final examination in the Calculus subject.

Table 1: Frequency Analysis

Demographic Profile	Variable	Frequency	Percent (%)
Gender	Male	100	68.5
	Female	46	31.5
Race	Chinese	2	1.4
	Indian	9	6.2
	Malay	135	92.5
Respondent Background	Student in Dept. of Civil Engineering	41	28.1
	Students in Dept. of Electronic Engineering	77	52.7
	Students in Dept. of Mechanical Engineering	28	19.2
Experience	No	60	41.1
	Yes	86	58.9
Device	Desktop	8	5.5
	Laptop/Notebook	104	71.2
	Smartphone	33	22.6
	Tablet	1	0.7
Type of Internet Connection	Mobile Data	96	65.8
	WIFI	47	32.20
	Wired/LAN Connectivity	3	2.1
Achievement	A	51	34.9
	A-	29	19.9
	B+	30	20.6
	B	13	8.9
	B-	7	4.8
	C+	12	8.2
	C	2	1.4
	D+	1	0.7
	D+	1	0.7

Table 2 shows descriptive data for independent and dependent variables. The participants' mean pointer was 3.44 (standard deviation, SD=0.62, range 1 – 4). The mean score for items in conceptual knowledge was 4.81 (standard deviation, SD=1.14, range 2.5 – 7), students' attitude toward learning calculus was 4.88 (standard deviation, SD=1.25, range 1.2 – 7), availability of supports was 5.31 (standard deviation, SD=1.05, range 2.86 – 7), and accessibility of infrastructure was 5.08 (standard deviation, SD=1.12, range 3 – 7).

Table 2: Descriptive Statistics

Variable	Mean	Std. Deviation	Minimum	Maximum
Pointer	3.44	0.62	1	4
Conceptual Knowledge through Online Learning	4.81	1.14	2.5	7
Students' Attitute toward Learning Calculus	4.88	1.25	1.2	7
Availability of Supports	5.31	1.05	2.86	7
Accessibility of Infrastructure	5.08	1.12	3	7

Linear Regression Analysis

As mentioned in the previous section, the study used multiple linear regression analysis to evaluate the conceptual knowledge through online learning (CK), students' attitude toward learning calculus (SA), availability of support (AS) and accessibility of infrastructure (AI) on the students' performance in calculus.

The correlation analysis results in Table 3 shows that only one independent variable which is CK (Conceptual Knowledge), has a significant relationship with the dependent variable, which is students' performance. However, for all independent variables, the correlation analysis reveals that there are weak correlates to the dependent variable. This might be due to the sample size, and the number of Higher Institution Education considered in this study. Although the results are not too encouraging to do the regression model, for the educational purpose, the study further built a regression model for the students' performance to ascertain how well the independent variables predict the students' performance in calculus.

Table 3: Correlation Analysis among Predictor Variables and Students' Performance (pointer)

		Pointer	CK	SA	AS	AI
Pointer	Pearson Correlation	1	.164*	0.027	0.066	0.013
	Sig. (2-tailed)		0.047	0.749	0.432	0.877
CK	Pearson Correlation	.164*	1	.845**	.724**	.786**
	Sig. (2-tailed)	0.047		0	0	0
SA	Pearson Correlation	0.027	.845**	1	.726**	.825**
	Sig. (2-tailed)	0.749	0		0	0
AS	Pearson Correlation	0.066	.724**	.726**	1	.827**
	Sig. (2-tailed)	0.432	0	0		0
AI	Pearson Correlation	0.013	.786**	.825**	.827**	1
	Sig. (2-tailed)	0.877	0	0	0	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4 summarises the study's findings on R Square and Adjusted R Square values, which are 0.083 and 0.057, respectively. These findings indicate that a weighted combination of the predictors can accurately predict 5.7% of students' performance.

Table 4: Summary of Standard Regression Analysis between Predictor Variables and Students' Performance in Calculus

R	R square	Adjusted R square	Std. error of the estimate
0.289	0.083	0.057	0.60012

Table 5: ANOVA for the Adequacy of a Regression Model

	Sum of Squares	Df	Mean Square	F	Sig.
Regression	4.617	4	1.154	3.205	0.015
Residual	50.780	141	0.360		
Total	55.397	145			

The study used conceptual knowledge through online learning, students' attitude toward learning calculus, availability of supports, and accessibility of infrastructure towards online learning as standard regression analysis to predict students' performance in calculus. Result in Table 5 reveal that the prediction model was found to be statistically significant, where the *p-value* =0.015 is less than a 5% level of significance. This indicates that is H_0 rejected and accept the H_1 where the conceptual knowledge determines the students' performance through online learning, students' attitude toward learning calculus, availability of supports, and accessibility of infrastructure towards online learning.

Table 6: Coefficients

		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
Model		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	3.141	0.261		12.047	0	2.626	3.657
	CK	0.292	0.087	0.537	3.36	0.001	0.12	0.464
	SA	-0.145	0.085	-0.292	-1.695	0.092	-0.314	0.024
	AS	0.053	0.086	0.09	0.612	0.542	-0.118	0.223
	AI	-0.134	0.099	-0.243	-1.362	0.175	-0.329	0.061

a. Dependent Variable: Pointer

From the analysis in Table 6, the average students' performance (pointer for Calculus subject) is 3.141 when conceptual knowledge through online learning, students' attitude toward learning calculus, availability of supports, and accessibility of infrastructure towards online learning are equal to zero. In this model, the students' performance is expected to increase by 0.292 points in their pointer to increase one level of their conceptual knowledge. However, each additional students' attitude toward learning calculus taken is associated with a decrease of 0.145 points of average students' pointer and each additional accessibility of infrastructure towards online learning taken is associated with a decrease of 0.134 points of average students' pointer in students' performance, assuming that all the independent variables is held constant.

Table 6 shows the order of significance of the independent variables by the absolute value of Beta. The independent variable with the highest Beta value is the most critical in terms of importance. When the contributions of the independent variables in the model were examined, it was discovered that the end-of-term scores obtained from the conceptual knowledge through online earning contributed the most, with a value of (Beta = 0.537). It was followed by the scores received from students' attitude toward learning calculus, accessibility of infrastructure, and availability of support, respectively. Although the contributions made by the scores obtained from students' attitude toward learning calculus, accessibility of infrastructure, and availability of support were significant, they were included in the model due to a regression analysis property. Its corresponding determination coefficients values are 0.292, 0.09, and 0.243, respectively, which revealed that it made the most negligible contributions to the model. Based on the regression analysis results, the regression model is obtained as in Equation (1),

$$\hat{y} = 3.141 + 0.292x_1 - 0.145x_2 + 0.053x_3 - 0.134x_4 \quad (1)$$

where $\hat{y}$ is the predicted pointer, x_1 is the conceptual knowledge through online learning, x_2 is students' attitude toward learning calculus, x_3 is availability of supports and x_4 is accessibility of infrastructure towards online learning. The study, however found students' attitude toward learning calculus, accessibility of infrastructure, and availability of support have no significant effect on students' performance in calculus. The data set was further analysed using the backward multiple linear regression analysis and forward multiple linear regression analysis to choose the best significant variable from the model. The result of the backward and forward regression analysis is shown in Tables 7 to 12.

Table 7: Summary of backward regression analysis between predictor variables and students' performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.289[a]	0.083	0.057	0.60012
2	.284[b]	0.081	0.061	0.59880
3	.267[c]	0.071	0.058	0.59987

a. Predictors: (Constant), CK, SA, AS, AI

b. Predictors: (Constant), AI, CK, SA

c. Predictors: (Constant), CK, SA

Table 8: ANOVA for backward multiple linear regression model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.617	4	1.154	3.205	.015[b]
	Residual	50.780	141	0.360		
	Total	55.397	145			
2	Regression	4.482	3	1.494	4.167	.007[c]
	Residual	50.915	142	0.359		
	Total	55.397	145			
3	Regression	3.939	2	1.970	5.473	.005[d]
	Residual	51.458	143	0.360		
	Total	55.397	145			

a. Dependent Variable: Pointer

b. Predictors: (Constant), CK, SA, AS, AI

c. Predictors: (Constant), AI, CK, SA

d. Predictors: (Constant), CK, SA

Table 9: Coefficient for backward multiple linear regression model

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.141	0.261		12.047	0.000
	CK	0.292	0.087	0.537	3.360	0.001
	SA	-0.145	0.085	-0.292	-1.695	0.092
	AS	0.053	0.086	0.090	0.612	0.542
	AI	-0.134	0.099	-0.243	-1.362	0.175
2	(Constant)	3.206	0.238		13.473	0.000
	CK	0.301	0.086	0.553	3.514	0.001
	SA	-0.144	0.085	-0.290	-1.684	0.094
	AI	-0.101	0.082	-0.183	-1.230	0.221
3	(Constant)	3.090	0.219		14.117	0.000
	CK	0.270	0.082	0.496	3.292	0.001
	SA	-0.195	0.075	-0.392	-2.604	0.010

a. Dependent Variable: Pointer

The analysis output from Tables 7 to 9 indicates the prediction model contained two of four predictors, and these were reaches in three steps with two variables removed. The model was statistically significant where the *p-value* is less than 0.05. The final model for the backward regression model is obtained as shown in Equation (2),

$$\hat{y} = 3.090 + 0.270x_1 - 0.195x_2 \quad (2)$$

where $\hat{y}$ is the predicted pointer, x_1 is the conceptual knowledge through online learning and x_2 is students' attitude toward learning the calculus.

Table 10: Summary of forward regression analysis between predictor variables and students' performance

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.164[a]	0.027	0.020	0.61180
2	.267[b]	0.071	0.058	0.59987

a. Predictors: (Constant), CK

b. Predictors: (Constant), CK, SA

Table 11: ANOVA for forward multiple linear regression model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.498	1	1.498	4.003	.047[b]
	Residual	53.899	144	0.374		
	Total	55.397	145			
2	Regression	3.939	2	1.970	5.473	.005[c]
	Residual	51.458	143	0.360		
	Total	55.397	145			

a. Dependent Variable: Pointer

b. Predictors: (Constant), CK

c. Predictors: (Constant), CK, SA

Table 12: Coefficient for forward multiple linear regression model

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	3.008	0.221		13.616	0.000
	CK	0.089	0.045	0.164	2.001	0.047
2	(Constant)	3.090	0.219		14.117	0.000
	CK	0.270	0.082	0.496	3.292	0.001
	SA	-0.195	0.075	-0.392	-2.604	0.010

a. Dependent Variable: Pointer

The analysis output from Tables 10 to 12 shows that the Adjusted R-squared increase from 0.020 to 0.058 by adding a second predictor. This indicated that the prediction model was reaching the optimise at the second steps with two variables added. The model was statistically significant where the *p-value* is less than 0.05. The final model for the forward regression model is obtained as in Equation (3),

$$\hat{y} = 3.090 + 0.270x_1 - 0.195x_2 \quad (3)$$

where $\hat{y}$ is the predicted pointer, x_1 is the conceptual knowledge through online learning and x_2 is students' attitude toward learning calculus, give the same result as the backward regression method.

CONCLUSION

Our lives have certainly been put on hold because of the COVID-19 pandemic. It has resulted in lockdowns and the closing of educational institutions. Given the circumstances, online learning became the best option, as it has in many other parts of the world. The obvious choice is online learning, and educators and students alike are excited to embark on a new adventure in this episode of COVID-19. According to Burgess and Sievertsen (2020) the lockdown of educational institutions not only prevents educators

and students around the world from teaching and learning, but also revolves around accurate assessments replace formal examinations that have been temporarily suspended.

Calculus continues to be a challenging subject for students. While studying online during a pandemic, students must gain conceptual knowledge to understand the concept of theory and how the concepts are connected to one another. Therefore, educators specifically the teachers and lecturers, and students must know how to use the technology and media communication during online class or lectures and the institutions need to provide good accessibility of support to the learning process in order to perform well in their Calculus subject.

The objectives of this study have been achieved, whereby is to investigate the impact of conceptual knowledge on student achievement in calculus taught through online learning. Statistical model of the student performance in calculus using regression method is developed, which considering students' attitudes towards calculus learning through online learning, the availability of support for online learning and the infrastructure facilities used for the online learning as the independent variables.

Based on the results that have been discussed in the previous section, the researchers found that two out of four factors in influencing student achievement are very important. In terms of infrastructure, researchers argue that not all students have a decent internet network. Several students have to pay high costs to access the internet data. Some students have to share the device with other siblings to succeed in the online learning. There are limitations of this study that should be taken in evaluating the results of the study. First, this study only looks at four factors, namely the accessibility of infrastructure, conceptual knowledge through online learning, availability of supports and students' attitude toward learning calculus. This study does not consider other factors such as household income factors, home geographical factors etc. Second, this study uses sample from students of an educational institution only. The result of this study might be different for students at other educational institutions. Therefore, the results of this study cannot be representative of the whole to students in all various institutions of higher learning. However, other institutions could use the proposed method used in this paper and apply it to their institution, which might result the coefficient values of the model different from this paper finding.

Stakeholders from other countries, such as mathematics curriculum developer, policymakers, teachers training colleges and university instructors, can use our proposed methodology model to predict their students' performance because predicting academic performance for students lets institutions overcome academic shortcomings and provides a framework for making the teaching and learning process more efficient, effective, and consistent. Based on the finding this paper, government or Ministry of Education could improve the education policy by considering factors which affects the students' performance. Hence, we could improve the online education system which recently very important in this COVID-19 situation.

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