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Analyzing the difficulty level in learning mathematics online using a quantile regression approach

***Leomarich F. Casinillo & Emily L. Casinillo**

Visayas State University, Baybay City, Leyte, Philippines

***Corresponding email:** leomarichcasinillo02011990@gmail.com

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Abstract

Online learning is a difficult type of educational process due to its limitations, particularly in college mathematics courses. The essential aim of this article is to elucidate the students' difficulty level in learning mathematics amid online learning and predict its statistically significant influencing factors. The data used in this study is secondary from a paper in the mathematics education literature on the form of cross-sectional. The data were summarized employing some descriptive measures and regression modeling as an inference. The result of the study showed that, on average, students are facing "difficulty" in learning their mathematics lessons during distance learning due to some problems. The quantile regression revealed that younger and female students are experiencing higher levels of difficulty. Plus, students who spent more money on the internet are facing higher difficulty in learning. In addition, a not conducive learning environment and social distractions are predictors of difficulty in learning. Conclusively, the difficulty in learning mathematics which adversely affects their performance is due to the distractions and problems in the learning environment, low coping mechanisms, and unprecedented educational process in the form of online setup. Hence, the study suggested that teachers must be flexible with students and provide digital simulations of mathematical problems, and use interactive models in their classes.

Keywords: Mathematics learning, online education, difficulty level, causal determinants, college students

INTRODUCTION

Being a mathematics student during the pandemic is not an easy undertaking because of the unprecedented difficulties in the educational process [27]. A quick shift from face-to-face to modular/online learning has made the classroom environment difficult to obtain the desired goals in education. Mathematics is one of the challenging courses to teach in college in the form of online education [8]. Many shortcomings were encountered by the mathematics teachers, especially in presenting the symbols and formula/equations [11], [18]. Plus, teachers were encountering uneasiness during the lockdown of the COVID-19 pandemic and facing some limitations as they do their job [15]. Meanwhile, students were uncomfortable and distracted in the online learning process amid the pandemic, hence, they cannot focus and penetrate to the cognitive process in their lessons. In addition, communication and interaction between teachers and students were hindered because of the misused of technology and internet connection problems [19]. In [18], it is stated that due to the difficulties encountered by the students, they tend to have a low understanding of their lessons which often led to low mathematics performance. In that case, students were in a bad way and uncomfortable with their learning ability in mathematics. According to the study in [9], the difficult and unprecedented experiences of mathematics students results in low happiness in learning and less creativity in the learning environment.

Seemingly, students residing in remote areas are mostly facing barriers to online learning due to bad internet connection and uneasy learning environments at their respective homes [11], [13], [18]. On the face of it, mathematics acquisition is adversely affected and the quality of learning is being diminished. In addition to that, in [25], it is mentioned that online learning in mathematics has been difficult to apply because of teachers' lack of training and experience wherein students are struggling to adjust to the cognitive process of distance education. The study in [30] portrayed that students amid the health crisis are being challenged in learning mathematics because of anxiety disorder, depression, and lack of interest in their studies. Moreover, in [31], it is depicted that students' low academic performance during the pandemic is governed by difficulties in online learning and unhappiness in their situation. Likewise, it is portrayed in [3] that students amid the health crisis are facing difficulties due to the lack of a conducive place to learn and due to distractions that cause them stress and anxiety. In that case, a thorough investigation of students' difficulty level in learning mathematics online is necessary to extract a remedy to increase the student's performance in distance education and to improve their well-being. This current study conjecture that the difficulty level of learning mathematics during the COVID-19 health crisis is influenced by the student's status and profile.

Several studies are being devoted to online education during the pandemic, however, the investigation of the difficulty level of students in mathematics learning using statistical modeling is scarcely studied. Plus, predicting the factors of students' difficulty level in learning using a quantile regression approach has never been realized. With that research gap, this current article study is conducted. In a general sense, this study ascertains the level of difficulty in learning mathematics in the form of online and modular learning and investigates the statistically significant predictors that causally influence it. Specifically, the article looks into the answers to the following goals: to summarize the profile of students as possible independent variables; to categorize and describe the difficulty level of students in learning mathematics at a distance amid the health crisis; to construct a quantile regression models that determine the influencing determinants of difficulty level in learning. The results of this article are hoped to provide a basis for mathematics educational policy that is suitable for online education. In addition to that, results may give some insights to improve the mathematics teaching strategies at the college level and provide information on how to improve the student's motivation and interest in learning despite the difficulties. Lastly, the findings of this article may serve as a piece of baseline information for distance education researchers and may be used as a benchmark for future research in the area of mathematics education.

The Conceptual Framework of the Study

When the closure of schools in higher institutions started due to the lockdown of the COVID-19 pandemic, the learning environment of college students changed to online education wherein unprecedented difficulties occurred [9], [10], [11], [18]. Teachers during this time were struggling to impart their knowledge in mathematics through poor communication in real-time discussions via the internet [7]. At the same time, students were having difficulties in grasping their lessons and being challenged in answering their learning tasks which resulted in the late submission of outputs [12]. With that, the quality of learning mathematics during distance education is not desirable and students' mathematical ability is declining. In the study in [10], the student's learning activities during the pandemic are being challenged because of the governing factors that are affected by the adverse impact of the health crisis. One of the factors as mentioned in [11], is the socio-demographic profile of students that hinders their study habits and learning focus. Students are facing difficulties in acquiring advanced technology and other needed school requirements due to the financial crisis [25]. Likewise, most of the students do not have a good internet connection and a conducive place for learning [18]. Another issue is that students are emotionally damaged due to the anxiety and low level of resilience that they are facing amid the pandemic [22]. Moreover, because of the high level of challenge in online education, students' interests and well-being are diminishing, and their desire in learning is negatively affected [23]. On the face of it, it is assumed that the difficulty level in learning mathematics is caused by the students' profile and mental and emotional experiences during the pandemic. Whence, the conceptual framework of this article correlates the students' socio-demographic and learning profile to their level of difficulty in learning mathematics during distance education. The framework is hoped to find solutions on how to improve the student's motivation

in learning and provide a new educational policy that will enhance the teaching strategies and well-being of both educators and students in times of unprecedented difficulties.

METHODOLOGY

The Design of the Research

A design that describes the variables of interest and determines the relationship between dependent and independent variables was utilized namely complex-correlational research. This type of research design was used to categorize and elucidate the level of difficulty in learning mathematics and forecast its governing determinants during distance learning. In that case, the design employed descriptive measures and statistical modeling in view of regression analysis.

The Respondents and Data Collection

The data utilized in this article are from the study by Casinillo et al. [11] that dealt with the determinants of challenge in learning mathematics at a distance during the COVID-19 pandemic. The respondents of the study were Mathematics of the Modern World (MMW) students at Visayas State University (VSU), Leyte, Philippines. The study has constructed a regression model that captures the governing factors of the level of challenge (how stimulating in facing difficulties) in mathematics learning under the online setup. However, the study does not concentrate on categorizing the level of difficulties using quantiles and determining the associating factors using quantile regression modeling. Hence, this current article is constructed. The data has been refined or homogenized wherein the extreme values were removed. In that case, the article has considered 132 MMW students. The selected dependent variable of this study is the level of difficulty in learning mathematics amid online learning and it is measured on a scale of 1 to 10, 1 being not difficult and 10 being extremely difficult. The following table presents the different categories of the level of difficulty.

Table 1. Possible difficulty perception score and its verbal description

Perception score	Difficulty category
1, 2	Not difficult
3, 4	Slightly difficult
5, 6	Moderately difficult
7, 8	Difficult
9, 10	Very difficult

As for the possible predictors, the study has chosen the following independent variables: age (in years), no. of hours studying mathematics (in a week), amount spent on the internet load (Philippine Peso (PHP)/week), internet connectivity (1 to 10 scaling), place of residence (Indicator (dummy) variable: 0=Rural, 1=Urban), gender of students (Indicator (dummy) variable: 0=female, 1=male), approximate family income (Philippine Peso (PHP)/month), coping with learning anxieties (1 to 10 scaling), how conducive is the learning place (1 to 10 scaling), leisure time (1 to 10 scaling), social activities (1 to 10 scaling), and health status (1 to 10 scaling).

Data Management and Empirical Model

Appropriate statistical measures were computed to summarize the selected variables in a tabular form and to give a meaningful description of the subject of interest in this study. Norman [26] in the year 2010 argued that ordinal type of data can be summarized with parametric methods, hence, mean average (M), standard deviation (SD) as measure of dispersion, coefficient of variation (CV) for the consistency of the response score, minimum (min) and maximum (max) values were employed. The chi-square test for uniformity was utilized to determine if the different difficulty level in learning follows a uniform

distribution. Basing the study of Seriño [29], quantile regression modeling was utilized to elucidate the level of difficulty in learning mathematics at a distance and capture its statistically significant influencing predictors. Quantile regression is more powerful than linear regression since it investigated the factors of difficulty in learning at different quantiles rather than just the mean average, in other words, quantile regression is an extension of ordinary least square (OLS) linear regression [21]. As for comparison, the OLS model was also run and interpreted. In that case, the regression model is postulated below:

$$Difficulty_i^Q = \partial_0 + \partial_1 Age_i + \partial_2 Hours_i + \partial_3 Minternet_i + \partial_4 Connectivity_i + \partial_5 Urban_i + \partial_6 maleS_i + \partial_7 FAMincome_i + \partial_8 Coping_i + +\partial_9 Conducive_i + \partial_{10} Leisure_i + \partial_{11} Social_i + \partial_{12} Health_i + \varepsilon_i$$

where $Difficulty_i^Q$ refers to three different quantile levels namely 25th, 50th, and 75th quantile (low, moderate, and high, respectively), and is the dependent variable in the model above, i can take the values from 1 to n where n is the number of respondents. Plus, ∂_j refers to the parameters of the model to be approximated where $j \in \{0, 1, \ldots, 9\}$. As for the regressors, Age_i refers to the age variable, $Hours_i$ refers to the approximate number of hours studying in a week, $Minternet_i$ refers to the approximate money spent on the internet, $Connectivity_i$ refers to the strength of the internet signal, $Urban_i$ is an indicator (dummy) variable that captures student who resides in urban places, $maleS_i$ is an indicator (dummy) variable that captures student who is male, $FAMincome_i$ refers to the approximate amount of family income within a month, $Coping_i$ refers to the coping level of students, $Conducive_i$ refers to how conducive are the students' place for learning, $Leisure_i$ refers to the rating of students on their leisure time, $Social_i$ refers to the level of students' social activity, $Health_i$ refers to the health status of students, and ε_i refers to the remaining random error of the above model. Results were tested at the appropriate level of significance and post-estimation techniques for the OLS model were also employed to ensure its validity. Calculations were done through STATA statistical program.

RESULTS AND DISCUSSION

Descriptive Profile

The summary of students' profiles during distance education is presented in Table 2. It shows that the approximate mean age is close to 19.76 (SD=0.98) years old wherein the youngest is 18 years old and the oldest student is 23 years old. These students have studied their mathematics lessons for approximately 5.73 (SD=7.25) hours in a week and the minimum hour is 1 and the maximum hours is 60. On average, these students spent 187.56 PHP (SD=178.45) for their internet connection. The minimum is 0.00 PHP since some students were just relying on family's internet connectivity and the maximum is 1000.00 PHP. Only 27% of these students are living in urban areas in the province and about 73% of them are living in rural areas where internet connection is somewhat problematic. There are more female (70%) students as opposed to male (30%) students. Their monthly family income is approximately equal to 18,610.83 PHP (SD=26,768.4 PHP) and there is a student during this time with no family income due to economic crisis and the maximum monthly income is 200,000.00 PHP.

Students' rating of their internet connection is close to 5.08 (SD=1.69) out of 10. This suggests that they are facing an internet problem in their respective places as they learn mathematics. Students' rating of their coping mechanism towards the difficulties in learning mathematics is relatively low (5.19 out of 10) (SD=1.83). This result suggests that it is challenging to focus and cope with their studies while facing some stressful and fearful situations brought about by the COVID-19 pandemic. The students' rating on their learning environment is close to 4.28 (SD=1.69) out of 10 which suggests that they do not make the best for learning due to their not conducive and distracting nature during the lockdown of the pandemic. Leisure time is also rated low (5.89 (SD=5.89) out of 10) since the lockdown has a lot of limitations and restrictions regarding physical contact and other recreation activities. Social status is rated as 6.71 (SD=2.11) out of 10, and this is somehow higher due to family bonding and social media coverage. Lastly, their health aspect is rated low as well (5.16 (SD=2.16) out of 10) due to the adverse impact of the pandemic which affects their mental and physical well-being.

Table 2. Summary of students' demographic and learning profile.

Demographic and learning profile (Independent Variables)	Mean	Standard deviation	Minimum	Maximum
Approximate age *(in years)*	19.76	0.98	18	23
The approximate number of hours studying statistics in a week	5.73	7.25	1	60
Approximate amount of money spent on the internet within a week[a]	187.56	178.45	0	1000
Urban residence *(dummy)*	0.27	0.45	0	1
Male students *(dummy)*	0.30	0.46	0	1
Approximate monthly family income[b]	18610.83	26768.4	0	200000
Rating of internet signal strength[a]	5.08	1.69	1	10
Rating of coping mechanism[a]	5.19	1.83	1	10
Rating of learning environment[a]	4.28	1.69	1	10
Rating of liesure time[a]	5.89	2.23	1	10
Rating of social status[a]	6.71	2.11	1	10
Rating of health aspect[a]	5.16	2.16	1	10

Note: a - Scale 1 to 10; b - Philippine Peso (₱).
Source: Authors' computation (2023).

Difficulty Level in Learning Mathematics Online

It is shown in Table 3 that there were only 7.58% of the students who does not experience difficulty in learning mathematics. About 9.09% of them said that mathematics online learning was slightly difficult, while 21.21% of them were facing moderate difficulty. On average, there were 28.79% of these students were having difficulty learning. Plus, dominantly of them (33.33%) said that mathematics distance education is very difficult for them. Based on the findings of the Chi-square test for uniformity, it shows that the frequency of students in the different difficulty levels does not follow a uniform distribution at a 1% level of significance. This means that it is statistically significant that more students are facing difficulty in learning mathematics during the pandemic. The mean average score shows that students are belonging to the difficult category. The study of Bestiantono et al. [5], portrayed that online learning does not create a positive outcome for students which makes it difficult to attain the desired academic performance. Moreover, according to Dontre in [14], students were distracted by social media and other websites, in which they cannot concentrate on their learning tasks in mathematics. Likewise, due to the limitations and barriers during the restrictions of the pandemic, students are experiencing stress and depression which negatively affects their cognitive behavior in learning [20]. However, Table 3 depicted that students' difficulty perception scores are "inconsistent" based on the coefficient of variation which is greater than 20%, that is, CV=35.49% > 20% [28]. This suggests that the students' difficulty level can be varied depending on the learning environment and current situation in the education process.

Table 3. Level of difficulty in learning mathematics at a distance.

Difficulty category	Frequency (n)	Percentage (%)	Chi-square computed	p-value (Two-tailed)
Not difficult	10	7.58	34.97*	<0.001
Slight difficult	12	9.09		
Moderately difficult	28	21.21		
Difficult	38	28.79		
Very difficult	44	33.33		
Total	132	100.00		
Mean±SD=6.96±2.47 (Difficult[b])				
CV=35.49 (Not consistent)				

Note: b - See Table 1; * - highly significant at 1% level.
Source: Authors' computation (2023).

Quantile regression model

As for the baseline of the quantile regression model, the OLS regression model is presented in Table 4. To ensure the credibility of the OLS model, diagnostics (post-estimation) tests for linear regression were utilized [1], [24]. The Breusch-Pagan test (X^2=0.28, p-value=0.59) portrayed that the fitted values of difficulty perception scores in the OLS model follow a constant variance and it is known as "homoscedastic". Additionally, the OLS model has no omitted variable bias in view of the Ramsey RESET test (X^2=0.28, p-value=0.59). Moreover, the OLS model is safe from multicollinearity trouble based on the variance inflation factor (VIF) which is lesser than 10, that is, VIF=1.54<10. In regard to the Shapiro-Wilk test (W=0.97, p-value=0.03), the residuals of the OLS model are not normally distributed since the null hypothesis (residuals follow a normal distribution) is rejected at a 5% level. However, it is shown in the figure below that the graph of the kernel density estimate of the residuals is approximately the same as the graph of normal density.

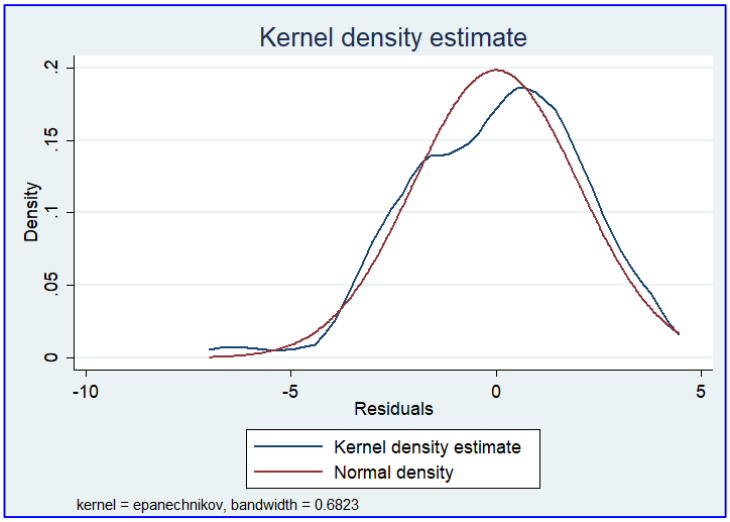

Figure 1. Kernel density estimate and normal density for residuals
Source: Authors' construction (2023).

Whence, the OLS model is valid and safe in interpreting its findings and gives statistically sound forecasting information to the subject of interest. In fact, the model is highly significant at a 1% level which indicates that there are several factors affecting the difficulty level of learning mathematics during online education. In addition, the coefficient of determination also depicts that the model has a model fit (R^2=0.335) which portrays that the level of students' difficulty in learning is governed by some causal factors namely their demographic and learning profile. In the lower level of difficulty in learning (25th quantile), the learning environment is significant at a 5% level as a determinant. This indicates that their environment is not conducive which gives them a negative influence on learning and results in a challenging educational process. This result is also true in the higher level of difficulty level (75th quantile) that the learning environment (at 10% level) is a significant factor that is a hindrance in good academic performance during online learning. Plus, the OLS regression also revealed that the learning environment (at 5% level) is a governing determinant of difficulty level in learning mathematics online.

This indicates that students are struggling to penetrate their lessons due to their existing problems and inconvenience in their learning environment during online education [4]. Additionally, younger students (at 10% level) are experiencing a higher difficulty in learning mathematics online and it is also true in the OLS regression model. This means that students with less experience in life are more anxious and with a low level of coping during difficult situations and that results in a challenge in learning online during the pandemic. This finding is in line with the study in [2] and [6] which depicted that younger students are facing difficulty in managing the challenges in their studies due to lack of experience and cognitive content. Students who spent more money on their internet connection (at 10% level) are a significant factor in a higher difficulty level in learning mathematics and it is supported by the OLS model. This means that they are anxious for money in buying the internet load which affects to their learning and

well-being as a student. According to Casinillo et al. [11], some families of students are facing a financial crisis during the pandemic and they are struggling to buy with their needs as well as students' requirements in their studies. Table 4 showed that female students (at 10% level) are facing a high level of difficulty as opposed to male students.

This implies that female students are more struggling to understand the concept of mathematics in the online learning setup compared to male students. According to the study in [16], male students are more active and better at learning mathematics than female students. In that case, the situation in online learning hinders the participation and motivation of a female student as opposed to a male and thus difficulty in learning levels up. Moreover, all levels of quantiles and the OLS model have revealed that social activities are a significant factor in the difficulty of learning mathematics online. This means that students are distracted by their social friends and family activities at home. On the face of it, they cannot focus on their studies since their minds are on social activities. In [17], social media and technology distractions often result in mind wandering and a lack of focus in online learning.

Table 4. Quantile and OLS regression model for difficulty level and its determinants.

Regressors	Regression Models (Quantile and OLS)			
	25th	**50th**	**75th**	**OLS**
Approximate age *(in years)*	-0.315ns	-0.433*	-0.419*	-0.367*
	(0.338)	(0.231)	(0.273)	(0.200)
The approximate number of hours studying statistics in a week	0.023ns	-0.008ns	-0.003ns	-0.005ns
	(0.046)	(0.029)	(0.031)	(0.026)
Approximate amount of money spent on internet within a week[a]	0.003ns	0.002*	0.002*	0.002*
	(0.002)	(0.001)	(0.001)	(0.001)
Urban residence *(dummy)*	-0.044ns	0.161ns	-0.539ns	-0.039ns
	(0.320)	(0.463)	(0.797)	(0.450)
Male students *(dummy)*	-0.319ns	-0.047ns	-0.971*	-0.315ns
	(0.896)	(0.527)	(0.552)	(0.436)
log (Approximate monthly family income[b]+1)	0.158ns	-0.077ns	0.037ns	-0.087ns
	(0.597)	(0.364)	(0.220)	(0.269)
Rating of internet signal strength[a]	0.165ns	0.103ns	-0.011ns	0.101ns
	(0.259)	(0.134)	(0.182)	(0.124)
Rating of coping mechanism[a]	0.083ns	0.195ns	0.181ns	0.165ns
	(0.231)	(0.234)	(0.208)	(0.117)
Rating of learning environment[a]	0.349**	0.206ns	0.239*	0.318**
	(0.159)	(0.215)	(0.187)	(0.131)
Rating of leisure time[a]	-0.199ns	0.234ns	0.178ns	0.074ns
	(0.197)	(0.229)	(0.177)	(0.125)
Rating of social status[a]	0.705***	0.446***	0.291*	0.398***
	(0.203)	(0.172)	(0.197)	(0.150)
Rating of health aspect[a]	-0.127ns	-0.055ns	-0.118ns	-0.087ns
	(0.272)	(0.217)	(0.199)	(0.127)
Constant	4.914ns	9.103*	12.006**	8.874**
	(7.391)	(5.264)	(5.178)	(4.186)
Observation	132	132	132	132
F-test computed	-	-	-	5.00***
p-value (Two-tailed test)	-	-	-	<0.001
R-squared	-	-	-	0.335
Pseudo R-squared	0.242	0.220	0.185	-

Note: a - Scale 1 to 10; b - Philippine Peso (₱); Standard errors are enclosed by parentheses; ns - not significant; *p-value<10%; **p-value<5%; ***p-value<1%.
Source: Authors' computation (2023).

CONCLUSION

This article looks into the students' difficulty level in learning mathematics during distance education online. The result of the study depicted that, on average, students in online learning were facing "difficulty" in grasping their mathematics lessons due to the obstacles and barriers in the learning environment. The regression models (Quantile/OLS) revealed young students have greater difficulty in learning as opposed to older students due to their lack of experience and coping mechanism. It is depicted that female students are struggling to understand their mathematics lessons compared to male students. In conclusion, male students are more active and resilient in the hardship of learning mathematical courses compared to female students. Plus, it is revealed that students are anxious about money for their school requirements especially for gadgets technology, and internet load which makes them more difficult to learn mathematics at a distance. Moreover, students are uneasy with the learning environment due to distractions and unfavorable educational processes. Students cannot concentrate because of unnecessary social and leisure activities in their learning environment. In that case, the study suggests that teachers must give interesting mathematics activities that motivate their students in learning despite the challenges they are facing in distance education. Teachers must provide a detailed solution manual for the mathematics lessons wherein students can easily follow and learn at their convenient time. Further, teachers must provide digital simulations in mathematical problem solving, and use interactive models in their classes to avoid boredom. It is highly recommended that for future studies, the teachers' perspective on students' experiences and performances in distance education must be investigated to further assess mathematics online learning during and beyond the pandemic.

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