Modeling students' innovativeness and its factors in learning mathematics amidst COVID-19 pandemic

Jenelyn V. Valenzona, Leomarich F. Casinillo* and Emily L. Casinillo

Department of Mathematics, Visayas State University, Visca, Baybay City, Leyte, Philippines
**Correspondence: leomarichcasinillo02011990@gmail.com*

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ABSTRACT

Innovation allows learners to cope with changes and discover new opportunities. This study aimed to investigate the students' level of innovativeness in learning mathematics amidst the COVID-19 pandemic. A non-probabilistic sampling of 132 students enrolled in Mathematics from Visayas State University were the respondents. Descriptive measures were used to summarize the results, and econometric modeling was constructed to determine significant determinants affecting students' innovativeness. On average, it was found that students considered themselves as "late majority adopters" during the pandemic. This implies that students during the pandemic are considered to have a low level of innovativeness in adopting the new normal activities in distance learning. Result revealed that household assets, monthly household expense, submission of outputs, and health significantly influence students' innovativeness in learning mathematics. Hence, the government must support the students with regard to learning technologies, and teachers should motivate students to adapt to the new setup of classes with an appropriate platform and meaningful activities. Furthermore, the government must prioritize the health of students as they learn during the pandemic.

Keywords: econometric modeling, influencing determinants, level of innovativeness, state university

INTRODUCTION

All sectors in the world, including mathematics education, have been adversely influenced by the effects of the COVID-19 pandemic. In fact, during this unprecedented time, students have difficulty learning mathematics due to some factors including availability of the internet connection (Sabaruddin et al. 2020), accessibility of technological tools (Aguilera-Hermida 2020), and intellectual unpreparedness and self-esteem (Harahap and Fitri 2021), among others. In connection, an in-depth understanding of the life experiences, perceptions, and motivation of students in learning mathematics amidst this crisis cannot be overemphasized. Likewise, Lin et al. (2016) stated that a teacher often has little time to assist individual students, and students often have no one at home to rely on for support. This leads to students' frustration, incomplete assignments, and ensuing poor performances on assessments. Hardship in learning mathematics from home is caused by the lack of learning resources such as not having access to the internet and parents' inability to support their children in the learning process (Putra et al. 2020; ADEC Innovations 2021; Harahap and Fitri 2021).

State universities in the Philippines have been adopting the "new normal" setting since the COVID-19 pandemic started. Collaboration of the global higher education and other societal stakeholders is a need to resolve instructive issues amid the pandemic (Lackie et al. 2020; Waizenegger et al. 2020). It must be the intention of Higher Education Institutions (HEIs) to continue providing quality education. In connection to providing quality education, students must be abreast of the unprecedented times when different learning tools are employed (Cortez 2020). It is worth noting that students' innovativeness plays an important role in affecting students learning mathematics amidst the COVID-19 pandemic. According to Rogers (2002), as cited by Kaminski (2011), innovation is an idea that is perceived as new by individuals. This refers to how individuals adapt to new things which are the basis of their success or failure (Lundblad 2003; Doyle et al. 2014).

Building innovation will reinforce the success in learning mathematics (Suyitno and Suyitno 2018). In that case, there is a need to explore students' innovative values. The level of students' innovation depends on their learning experiences and factors affecting their innovative characteristics. Literature studies revealed that individual innovativeness is influenced by determinants such as demographic profile (Coklar 2012; Ertug and Kaya 2017), learning styles (Incik 2020), learning environment (Konings et al. 2008), e-Learning (Ozcan et al. 2016; Aldahdouh et al. 2020), leisure time (Marques and Biscaia 2019), social relationships (Glinska-Newes et al. 2017) and health aspects (Ikiz and Asici 2017). Hence, the conceptual framework of this study assumes that students' innovativeness is influenced by the mentioned determinants above.

Furthermore, several studies used the Individual Innovativeness Scale (IIS) developed by Hurt et al. (1977) to determine the level of the individuals' innovativeness (Coklar 2012; Ozcan et al. 2016; Parlar and Cansoy 2017; Ali 2019; Incik 2020). Liberna et al. (2021) defined innovativeness in learning mathematics as the adoption of new technologies in accordance with the time being. Moreover, innovation in learning mathematics refers to the new strategies and approaches in solving problems (Hendriana et al. 2019) and it also refers to a creative way of thinking about new ideas (Casinillo et al. 2020). In that case, comprehending the level of students' innovativeness in learning mathematics amidst the pandemic will clarify a deeper intelligence of well-being of students in mathematics education. Therefore, this study is conducted.

Henceforward, the goal of this study was to examine the different determinants that affect students' level of innovativeness in learning mathematics. Precisely, the study sought to answer the following specific objectives: (1) to estimate the level of individual innovativeness in learning; and (2) to construct econometric models and document significant determinants (socio-demographics) that would affect the level of individual innovativeness among students. Results of this study may offer some inputs to educators on strategies and methodologies to maintain a quality teaching-learning process amidst the COVID-19 pandemic.

METHODS

Research Design

The research design of this study is complex correlational that deals with econometric models based on the theory of Individual Innovativeness to address the study's objectives. Primary data were collected on socio-demographic profiles, learning styles, social relationships, health, and individual innovativeness through a developed instrument by Hurt et al. (1977). In describing the data, descriptive measures were used such as percentages, minimum value, maximum value, mean, and standard deviation. For further analysis, ordered logit modeling was constructed to determine the significant factors of students' innovative characteristics in learning mathematics.

Respondents, Ethical Considerations and Research Reflexivity

The respondents of this study were college students enrolled in Mathematics in the Modern World (MMW) during the 2nd semester for the academic year 2020-2021 in Visayas State University (VSU). The survey was made using a Google form and sent via email. The online survey link was posted in the virtual classroom and was forwarded by the faculty to their respective students. In addition, the online survey link was posted on Facebook and the e-learning environment. In this study, a non-probabilistic sampling technique was employed since it applies a non-random method, that is, students who willingly participate in the survey were automatically part of the sample. The survey was open for about three weeks, and a total of 132 out of 564 students responded to the Google form questionnaire. This sample size (132 respondents) is considered large and can suffice to construct econometric models (Jenkins and Quintana-Ascencio 2020). Before the conduct of the survey, a formal letter was sent to the head of the Department of Mathematics and Physics to ask for permission. Before answering the questionnaire, students were informed that the information gathered from them will be treated with high confidentiality in accordance with Data Privacy Act (Republic Act 10173) and their participation was voluntary. In addition, it was explained to students that this study could be used as basis in enhancing their learning style in mathematics. Moreover, the study specifically provides educators with perspectives on how to sustain the needs of students in learning. Despite the influence of COVID-19 to education, flexibility and innovation are essential characteristics students must possess. Likewise, teachers must give quality education and be realistic when they know students' innovative characteristics.

Research Instrument and Data Collection

The questionnaire is composed of the socio-demographic profile, learning styles about flexible learning, school background, and scale of measurement on individual innovativeness in learning mathematics. In the socio-demographic profile, students were asked about the following: age (in years), sex (1=male, 0=female), hometown (1=Urban, 0=Rural), availability of laptop(s) (1=Yes, 0=No), number of hours studying mathematics lessons per week, amount of money spent on internet connection per week (in peso), household size, household assets (in peso), monthly income of the family (in peso), and monthly household expenses (in peso). As to the learning styles about flexible learning, students were asked about the following: preference on learning event (1=asynchronous, 0=synchronous), submission of outputs on-time (1=Yes, 0=No), preferred Learning Modality System (LMS) (1=MOODLE or VSU E-Learning, 0=Other LMS), signal strength using a 10-point Likert scale, 1-Poor, and 10-High, and coping with math anxieties and resiliency using 10-point Likert scale, 1-Slow and 10-Very quick. Table 1 presents the evaluation of the strength of internet connection and coping with math anxiety and resiliency based on the mean perception score.

Table 1. Mean perception score and its over-all rating.

Range of Mean Perception	Over-all rating
1.00–2.80	Very Poor/Very Slow
2.81–4.60	Poor/Slow
4.61–6.40	Satisfactory
6.41–8.20	High/Quick
8.21–10.00	Very High/Very Quick

For other factors in learning mathematics, a 10-point Likert scale was used, 1-Not satisfied at all and 10-Very satisfied. These factors were learning environment, leisure time during the COVID-19 pandemic, social relationships, and health aspects. Table 2 shows the range of mean perception scores and their corresponding description of the different factors in learning mathematics.

Table 2. Mean perception score and its description.

Range of Mean Perception	Description
1.00–2.80	Very Unsatisfied
2.81–4.60	Unsatisfied
4.61–6.40	Neutral
6.41–8.20	Satisfied
8.21–10.00	Very satisfied

Moreover, a measurement on Individual Innovativeness by Hurt et al. (1977) was used to determine the students' innovativeness in learning mathematics. This measurement is composed of 20 statements using a 5-point Likert scale, that is, 1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly Agree. The scoring point of Individual Innovativeness is = 42 + (total scores of the 1st, 2nd, 3rd, 5th, 8th, 9th, 11th, 12th, 14th, 16th, 18th, and 19th items) – (total scores of the 4th, 6th, 7th, 10th, 13th, 15th, 17th, and 20th items). For interpretation, the evaluation criteria presented in Table 3 were used.

Table 3. Evaluation criteria of students' level of individual innovativeness.

Range of Scores	Classification
80 and above	Innovators
Between 69 and 80	Early Adopters
Between 57 and 68	Early Majority
Between 46 and 56	Late Majority
46 and below	Laggards/Traditionalists

Data Analysis

For the data analysis, descriptive statistics were employed to summarize the different responses of students such as mean, standard deviation, statistical graphic (pie chart), and Statistical Packages for Social Sciences (SPSS) version 20.0 was used for accurate calculation. Ordered logit modeling was performed to capture the different significant determinants that influence the students' innovativeness during the COVID-19 pandemic. Moreover, some diagnostic tests were employed to ensure a valid inference from the models such as the homoscedasticity test (Breusch-Pagan test), omitted variable test (Ramsey RESET test), multicollinearity test, and normality test for residuals (Shapiro-Wilk test). All calculations in modeling were aided with STATA version 4.0.

RESULTS

Level of Individual Innovativeness

The students' innovativeness mean score measured by the IIS was calculated as 55.46 (± 7.02) which can be interpreted that students were in the category of late majority (Table 3) with regard to learning amidst the pandemic. The majority of the students considered themselves as the late majority (54%) and the early majority (37%). About 3% of them were found to be early adopters. It was also revealed that only 6% of the students found themselves as laggards (Figure 1). Moreover, no student was found to be an innovator.

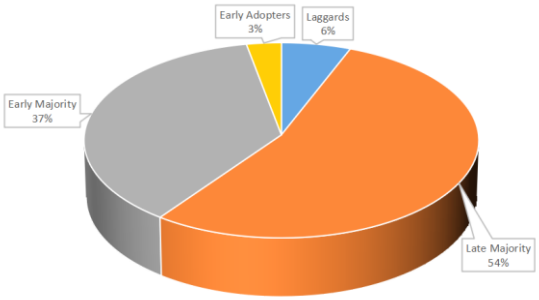

Figure 1. Classification of students' innovativeness.

Determinants of Individual Innovativeness and Econometric Models

The socio-demographic variables of the college students show possible determinants of individual innovativeness (Table 4). The age of the students ranged from 18 to 33 years old (19.89 ± 1.76), and there were 30% (0.30 ± 0.46) male and 70% female. About 70% (0.70 ± 0.50) of students had laptop/s, while 30% did not have. Approximately 27% (0.27 ± 0.44) of the students lived in urban places and 73% lived in rural areas. The number of hours of studying mathematics lessons (per week) ranged from 1 to 60 h, and the amount of money spent on internet connection (per week) ranged from PHP 0 to PHP 1,000. The household size of students ranged from 2 to 12, and their household assets ranged from PHP 2,000 to PHP 4,500,000. On average, students' monthly family income was PHP 18,547.52, and their

monthly household expenses were PHP 11,546.51. More than (0.54 ± 0.50) of students preferred asynchronous classes, while 46% preferred synchronous classes, and 26% (0.26 ± 0.44) usually submitted their outputs on time, while 74% did not usually submit their outputs on time. Students who preferred Modular Object-Oriented Dynamic Learning Environment (MOODLE) as the Learning Modality System (LMS) was 50% (0.50 ± 0.50) and others preferred other LMS. On average, the strength of the internet connection was neutrally satisfactory (5.02 ± 1.73). On average, students could satisfactorily cope with math anxiety (5.20 ± 1.88), and neutrally satisfied in view of their resiliency (5.32 ± 1.75). The students were unsatisfied with the learning environment (4.24 ± 1.69), while they were neutrally satisfied in leisure activities during the COVID-19 pandemic (5.58 ± 2.22). Furthermore, results showed that students were satisfied with their social relationships (6.71 ± 2.12), and they were neutrally satisfied in terms of their respective health (5.16 ± 2.15).

The diagnostic tests implicitly determined whether an econometric model is appropriately specified in regards to the regressors (O'Connell and Liu 2011). Hence, by Breusch-Pagan test, it showed that the variances of the four models had no problem, that is, the models were homoscedastic (Model 1: $\chi^2 = 0.85$, $P = 0.36$; Model 2: $\chi^2 = 2.03$, $P = 0.15$; Model 3: $\chi^2 = 3.57$, $P = 0.06$; Model 4: $\chi^2 = 0.51$, $P = 0.47$). Using the Ramsey RESET test, it revealed that the four models possessed no omitted variable bias, that is, the model did not leave out one or more appropriate variables (Model 1: $F = 0.55$, $P = 0.65$; Model 2: $F = 0.66$, $P = 0.58$; Model 3: $F = 1.23$, $P = 0.30$; Model 4: $F = 1.01$, $P = 0.38$). Regarding the multicollinearity test, the four models had safely ignored a multicollinearity problem using Variance Inflation Factor (VIF), that is, VIF<10. Furthermore, by the Shapiro-Wilk test, the four models had no problem for normality of residuals (Model 1: $Z = -0.13$, $P = 0.55$; Model 2: $Z = 0.61$, $P = 0.27$; Model 3: $Z = -0.784$, $P = 0.78$; Model 4: $Z = 1.39$, $P = 0.08$). Hence, the models were valid for drawing inferences.

Table 4. Descriptive measures for socio-demographic variables of students (n = 132). a-dummy (indicator) variable; b-Philippine Peso (PHP); c-Scale 1 to 10.

Socio-demographic variables	Mean ($\bar{x}$)	Standard deviation (± sd)	Minimum value	Maximum value
Age (in years)	19.89	1.76	18	33
Male[a]	0.30	0.46	0	1
Urban[a]	0.27	0.44	0	1
Availability of laptops(s)[a]	0.70	0.50	0	1
Number of hours studying math lesson (per week)	5.72	7.26	1	60
Amount of money spent on internet connection (per week)[b]	187.71	176.91	0	1000
Household Size	6.10	2.23	2	12
Household Assets[b]	150631.36	535588.50	2000	4500000
Monthly Income of Family[b]	18547.52	26687.46	880	200000
Monthly Household Expenses[b]	11546.51	12254.62	1000	80000
Asynchronous[a]	0.54	0.50	0	1
Submission of Outputs[a]	0.26	0.44	0	1
Modular Object-Oriented Dynamic Learning Environment (MOODLE)[a]	0.50	0.50	0	1
Signal Strength[c]	5.02	1.73	1	10
Coping with Math Anxiety[c]	5.20	1.88	1	10
Coping with Resiliency[c]	5.32	1.75	1	10
Learning Environment[c]	4.24	1.69	1	10
Leisure Time during Covid-19 Pandemic[c]	5.85	2.22	1	10
Social Relationships[c]	6.71	2.12	1	10
Health Aspects[c]	5.16	2.15	1	10

Table 5. Econometric models for students' innovativeness in learning mathematics and its influencing determinants (n = 132). a-dummy (indicator) variable; b-Philippine Peso (PHP); c-Scale 1 to 10. Standard error is enclosed with parenthesis; $*P < 0.10$; $**P < 0.05$; $***P < 0.01$, ns-not significant.

Independent Variables	Ordered Logit Models			
	Model I	**Model II**	**Model III**	**Model IV**
Age (in years)				0.0089^{ns} (0.1011)
Urban[a]	-0.4474^{ns} (0.4264)			
Male[a]		0.3188^{ns} (0.4050)		
Availability of laptops(s)[a]		-0.3160^{ns} (0.3985)		
Number of hours studying math lesson (per week)	0.0151^{ns} (0.0241)			
Amount of money spent on internet (per week)[b]			-0.0008^{ns} (0.0011)	
Household Size				0.0883^{ns} (0.0831)
Household Assets[b]	0.4882** (0.2162)	0.5250** (0.2259)	0.5141** (0.2187)	2.64e-07^{ns} (3.64e-07)
Monthly Income of Family[b]			0.0047^{ns} (0.2936)	
Monthly Household Expenses[b]	0.5621** (0.2706)	0.5843** (0.2701)	0.5297* (0.3028)	0.6019** (0.2629)
Asynchronous[a]	0.2320^{ns} (0.3677)		0.2269^{ns} (0.3652)	
Submission of Outputs[a]	0.8852** (0.4357)	0.8160* (0.4489)	0.6281^{ns} (0.4341)	0.9703** (0.4335)
Modular Object-Oriented Dynamic Learning Environment (MOODLE)[a]	-0.2323^{ns} (0.3731)			
Signal Strength[c]		0.0226^{ns} (0.1178)		
Coping with Math Anxiety[c]				0.0727^{ns} (0.1068)
Resiliency[c]			0.1540^{ns} (0.1137)	
Learning Environment[c]				-0.1163^{ns} (0.1241)
Leisure Time during Covid-19 Pandemic[c]		0.0089^{ns} (0.1048)		
Social Relationships[c]				0.0848^{ns} (0.1216)
Health Aspects[c]	0.2888*** (0.0889)	0.2696** (0.1108)	0.2577*** (0.0924)	0.2286** (0.1208)
Chi-squared	28.49	27.87	29.29	23.44
P-value (*P*)	0.0004	0.0005	0.0003	0.0053
Pseudo R-squared	0.1104	0.1080	0.1135	0.0909

The four econometric models have the statistically significant factors to students' innovativeness in learning mathematics (Table 5). Four models were created to make use of all the possible variables affecting students' innovativeness. It is shown that the five models were significant, which implies that there were factors influencing students' innovativeness. However, the four models revealed a small goodness-of-fit (Model 1: Pseudo $R^2 = 0.11$; Model 2: Pseudo $R^2 = 0.11$; Model 3: Pseudo $R^2 = 0.11$; Model 4: Pseudo $R^2 = 0.09$). Thus, there were only a few significant variables that affect innovativeness amidst the pandemic. This implies that students are in the shock of adjusting to the new normal process of distance learning. Model 1 and 2 disclosed that the significant factors influencing students' innovativeness were household assets, monthly household expense, submission of outputs on time, and health aspects. These results were also supported by Model 3. It revealed that household assets, monthly household expenses, and health have influenced the innovativeness of students during the pandemic. Likewise, Model 4 also revealed that

monthly household expenses, submission of outputs on time, and health aspects were significant factors.

DISCUSSION

Level of Individual Innovativeness

Results revealed that, on average, students are considered as a late majority in view of their innovativeness in learning. Hence, these students during the pandemic are resistant to adopting the new normal activities and the use of technology in distance learning. It is concluded that the impact of the COVID-19 pandemic influences the students' anxiety in learning mathematics which results in unproductivity and a low level of innovativeness. Students were cautious about innovations and are reluctant to adopt the use of technology platforms (Doyle et al. 2014). Amidst this COVID-19 pandemic, students felt that they learn better in physical classrooms than through online classes as pointed out in the study of Chakraborty et al. (2021). Likewise, in the study of El Firdoussi et al. (2020), students specified that online learning was not interesting compared to the traditional learning setup. During the pandemic, students are still adjusting to a new setup of classes by creating new routines, trying new activities, and maintaining social connections (Logel et al 2021). In that case, teachers must give some interesting activities with the aid of the advancement of technologies (mathematics software programs) so that students at a distance can develop their innovativeness in learning mathematics.

Determinants of Individual Innovativeness and Econometric Models

The econometric model reveals that household assets, monthly household expenses, submission of outputs, and health of students are the only significant contributors to their innovativeness. It suggests that household assets positively influence the students' innovativeness at their respective homes due to the diverse technology they possess. This result is aligned to Ansong et al. (2015) which revealed that asset possessions impact students' academic achievement. Students with more assets have lots of opportunities to become more creative in learning amidst this pandemic. Likewise, more asset possessions may build their creativity which influences individual innovativeness. Such result is inconsonant with Casinillo et al. (2020) that dealt with a creative learning experience in mathematics. The monthly household expense also has contributed to the students' innovativeness through benefits and comforts of buying goods and services. This means that if the parents of students can afford some tools to aid their education, students have the advantage to deal with distance learning compared to students with low-income families (Melguizo et al. 2016). Casinillo (2019) found that financial problems led to low performance in mathematics. Conclusively, financial stability is very crucial amidst the pandemic. However, the COVID-19 pandemic caused an economic crisis that affected the family income. This means that parents cannot provide some requirements for distance learning which deteriorates students' innovativeness. A financial crisis within households leads to students' declining interest in education.

Moreover, submission of outputs in distant learning influences the innovative skills of students. This suggests that students are eager to finish their given tasks on or before the given deadlines using technology devices during the pandemic. Shuja et al. (2019) found that the usage of devices is good in providing a flexible teaching-learning process and boosts up their assessment outputs on time. The study of Han and Yi (2019) explained that the use of smartphone technology of students positively affects their academic performance. Furthermore, a healthy student is more likely innovative in learning mathematics amidst the pandemic. The study of Jeffries and Salzer (2020) justified that students with health condition results in poor academic achievement and self-efficacy. As explained by Casinillo and Casinillo (2020), health is a predictor of students' motivation in learning. This goes to infer that good health boosts the students' interest and motivates them to do something innovative in the teaching-learning process during distance learning. In addition, students' good health condition goes with the ability to cope with stress in these unprecedented times. On the other hand, results reveal that some demographic profiles such as age, hometown, sex, and household size are independent of the students' innovativeness. Likewise, leisure activities and social relationships do not influence their level of innovativeness amidst pandemic. This is due to the travel restrictions, early curfew, liquor ban, physical distancing, and other restrictions imposed by the national government to combat the spread of the COVID-19. Panarese and Azzarita (2021) divulged that the government restrictions during the pandemic harm the psychological and social well-being of young individuals. Moreover, variables related to distance learning such as availability of laptops, number of hours of studying the subject per week, money spent for the access of internet connection, asynchronous online learning, MOODLE learning environment, signal strength, coping math anxiety, and resiliency are not significant factors of innovativeness.

An unplanned and quick shift to online learning with no sufficient experience resulted in unproductivity and a low level of innovativeness (Li and Lalani 2020). Furthermore, an unconducive place for learning, and without a stable internet connection

led to anxiety and struggle in learning as they participate in their online classes. Similarly, Alvarez (2020) found that distance learning amidst the pandemic was quite challenging not only for internet concern but also for the financial stability of each household that affected and interrupted their learning commitment. On the face of it, teachers must adopt an approach that is suitable for distance learning like giving the students student-friendly learning materials in mathematics with interesting real-life problem examples. In this manner, students who have difficulty in acquiring a good internet connection can also learn despite the challenges brought by the pandemic. According to Khirwadkar et al. (2020), it is necessary to use innovative ideas to evolve teaching strategies in mathematics to maintain a sustainable mathematics education amidst the crisis.

Hence, mathematics teachers are to provide students with necessary and reliable activities amidst the pandemic which will bring them to the adaption of appropriate technology in instruction. This is to prepare them to adapt to changes in instruction and technologies used in their educational endeavors. Teachers must focus on students' creativity that will lead them productive even in their lack of technology resources. Moreover, teachers must provide mathematical activities that are fit for time constraints and feasible during the pandemic. Hence, teachers must not give activities that may jeopardize students' health or may violate some government health protocols during the pandemic. For future research, one may consider the students' happiness or subjective well-being in learning mathematics amidst the pandemic which is a limitation of the current study.

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