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Modelado de la relación entre las características demográficas digitales, la alfabetización digital y el rendimiento académico de estudiantes de matemáticas en un Entorno de aprendizaje en línea

Modeling the Relationship among Digital Demographic Characteristics, Digital Literacy, and Academic Performance of Mathematics Major Students in an online Learning Environment

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RESUMEN

El propósito del estudio fue determinar las características demográficas digitales, la alfabetización digital y el rendimiento académico de los estudiantes de matemáticas en un entorno de aprendizaje en línea, así como modelar las relaciones entre estas variables. Para medir y obtener los datos necesarios, el estudio empleó un diseño de investigación de correlación predictiva y un cuestionario de investigación adaptado. Se realizó una encuesta con una muestra aleatoria de 322 estudiantes de los campus principales y externos de la universidad estatal de interés. Se realizaron una serie de regresiones y análisis de ruta para explorar cualquier variable significativa que pudiera describir las relaciones entre las variables estudiadas. Principalmente, el estudio encontró que los niveles de investigación, recuperación y gestión de la información mediaron total y significativamente las relaciones entre la disponibilidad de dispositivos tecnológicos, el uso de una plataforma electrónica de aprendizaje y el rendimiento académico en matemáticas de los estudiantes. En la validación del modelo, el segundo modelo demostró la consistencia de variables como la investigación y recuperación de información y la alfabetización en gestión de información al influir indirectamente en las relaciones entre la disponibilidad de dispositivos tecnológicos y el rendimiento académico. Se puede realizar un estudio junto con este estudio para utilizar el modelo diseñado en este estudio en otras ubicaciones para validar aún más la coherencia general del modelo.

PALABRAS CLAVE

Alfabetización digital; características demográficas digitales; rendimiento académico en matemáticas; aprendizaje en línea; análisis de ruta.

ABSTRACT

The purpose of the study was to determine the digital demographic characteristics, digital literacy, and academic performance of students majoring in mathematics

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in an online learning environment, as well as to model the relationships between these variables. To measure and obtain the necessary data, the study employed a predictive-correlation research design and an adapted research questionnaire. A survey was conducted with a random sample of 322 students from the main and external campuses of the state university of interest. A series of regressions and path analyses were conducted to explore any significant variables that could possibly describe the relationships among the studied variables. Principally, the study found that the levels of information research, retrieval, and management completely and significantly mediated the relationships among the availability of technological devices, use of an electronic learning platform, and students' academic mathematics performance. In the model validation, the second model demonstrated the consistency of variables such as information research and retrieval and information management literacy in indirectly influencing the relationships between technology device availability and academic performance. A study may be conducted in conjunction with this study, to use the model devised in this study in other locales to further validate the model's overall consistency.

KEYWORDS

Digital literacy; digital demographic characteristics; mathematics academic performance; online learning; path analysis.

1. Introduction.

Globally, higher education institutions (HEIs) have made major changes and upgrades to their educational environments; for instance, virtual or online instruction is replacing traditional face-to-face instruction (Asio et al., 2021; Crawford et al., 2020). These shifts in the field of education brought about by the COVID-19 pandemic raise multiple issues regarding the students' readiness, preparedness, and literacy (World Bank Group Education, 2020). Despite the fact that we are currently living in the technological era of the Fourth Industrial Revolution (Alakrash & Abdul Razak, 2021), the COVDI-19 wreaked havoc, compelling everyone to be technologically literate, with education being one of the areas requiring this literacy. As a result, students' readiness to attend synchronous and asynchronous classes using various online learning platforms, as well as their competency in the various digitals that can support their learning, plays a crucial role; these are factors that limit the potential to fully adopt the new mode of instruction, particularly in developing countries (Asio et al., 2021; Alipio, 2020; Baloran, 2020).

Various government and non-government organizations exerted efforts to provide a quick response so that the impact of the pandemic on education may be alleviated. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) keeps track of the policy measures taken by governments all over the world in response to the disruption that COVID-19 has caused in the education sector, such as school closings (UNESCO, 2020). The Southeast Asian Minister of Education Organization (SEAMEO) provides monitoring updates on COVID-19 and responses among member countries, as well as numerous online resources required to support virtual teaching and learning initiatives, such as their website, which features smart educational materials that learners and educators can download for free (SEAMEO, 2020). In a similar vein, the International Education (IE), UNICEF, and World Bank have continued to collaborate with international organizations and governments in each of these regions. This has been attained by collecting and monitoring evidence and sharing guiding principles, knowledge, recommendations, and technical expertise to support education that was severely affected by the pandemic (Reuge et al., 2021; Education International, 2020; World Bank Group Education, 2020). Although flexible learning appears to be the most effective technique to address existing learning gaps amongst students in the academic arena, there are still significant gaps in students' and instructors' lack of preparedness and competency in utilizing this approach (Murgatrotd, 2020). Issues on inadequate internet access, shortage of devices for online learning, lack of technical expertise, school equipment and internet availability, and faculty development contribute sig-

nificantly to determining the effectiveness of the implementation of online and flexible learning education (Asio et al., 2021; Aboagye et al., 2021; Zaharah & Kirilova, 2020).

These challenges with digital preparation, literacy, and access to digital technology among students are evident (Naidoo, 2020), and technology integration, particularly in mathematics education, has a significant impact on mathematics learning (Naidoo, 2020; Wahyuni, 2021). Students majoring in mathematics are severely impacted by the abrupt shift in teaching and learning modalities, and many changes and measures must be considered in order to continue studying and learning mathematics, especially that several major subjects and skills are best learned in a face-to-face setting, since traditional classrooms with face-to-face instruction are the ideal settings to study mathematics (Khirwadkar et al., 2020). In a virtual or online classroom setting, the difficulty of the lesson's delivery and content, especially when it involves mathematical computation, is compounded for both students and instructors (Cassibba et al., 2021; Irfan et al., 2020). Consequently, the study of mathematics has evolved to heavily rely on a range of digital platforms and devices to facilitate teaching and learning.

There is a paucity of study on students' digital readiness and literacy, particularly among mathematics majors, and how these variables affect or influence their level of mathematical achievement in a virtual or online learning environment in higher education. The plurality of studies on mathematics learning in tertiary institutions did not concentrate on this area (Alabdulaziz, 2021; Mendoza et al., 2021; Mulenga & Marbán, 2020). However, there have been attempts to investigate students' competence, literacy skills, and difficulties in studying mathematics in higher education through an online modality, but these studies have mostly focused on the teacher's perspective rather than the students' (Cassibba et al., 2021; Maital et al., 2020; Irfan et al., 2020). Similarly, a study was undertaken during the COVID-19 pandemic to evaluate how students used digital platforms to learn mathematics, with an emphasis on postgraduate mathematics education students (Naidoo, 2020). Meanwhile, only the study of Zulkarnain et al. (2020) attempted to quantify the digital literacy of mathematics students participating in an online learning environment. As a result, there is an evident of scarcity of studies that measure digital literacy among mathematics majors in an online learning environment.

This study argues for the evaluation of mathematics students' digital demographics, digital literacy, and mathematics academic performance to fill in the gaps in the existing literature. Specifically, this study delves into exploring the best model that describes the relationship among the digital demographic characteristics, digital literacy, and academic performance of the respondents. The findings of this study were seen as beneficial to the university would have a clear picture of the students' digital preparedness, readiness, and literacy in order to identify critical interventions for the implementation of flexible learning modalities.

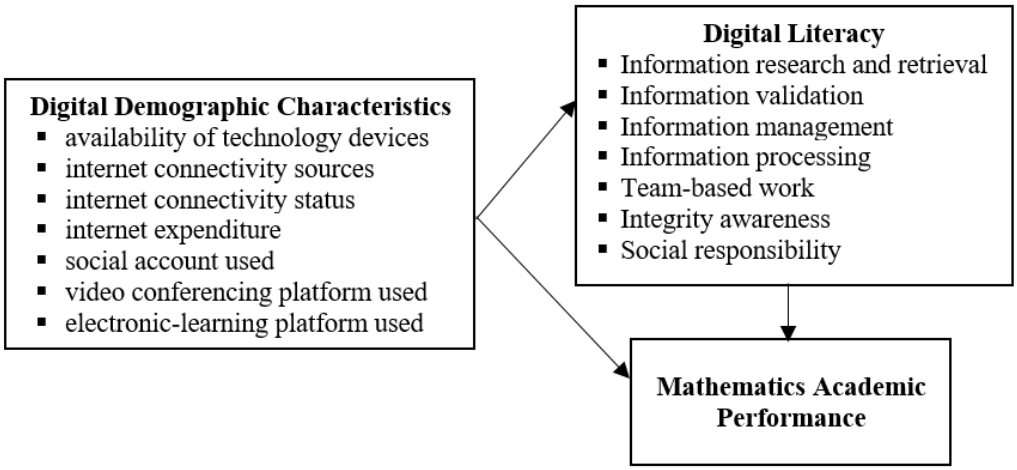
1.1. Framework of the Study.

The study was anchored on the theory of Self-Efficacy (Bandura, 1977), which asserts an individual's self-confidence, self-assurance, and trust in his or her own abilities and capabilities to achieve a desired performance. Online learning has been linked to self-efficacy in operating computers and other types of technology (Hammer, 2020). This enables students to assess their own digital literacy on their own, which is extremely useful when completing online classes that isolate them socially and relying on an autonomous learning strategy. Moreover, Gibson's (1977) Affordance Theory refers to objectively measurable action possibilities in the physical environment that only become evident in response to an agent. The theory explains that the affordances (functions or uses) of the different technological tools, such as mobile phones, laptops, tablets, and so on, may be clearly demonstrated as soon as the agent, who in this context is represented by the students, utilizes them. The degree to which technologies are usable and useful can be determined by the literacy or competencies demonstrated by the students. Furthermore, the theory explicates and backups the importance of identifying one's own digital technology characteristics, which include digital technology device availability, internet accessibility, social media account usage, video conferencing platform usage, and e-learning platform usage,

and examining their link to academic performance, so does the extent of digital literacy of the students and its relationship with academic performance. Figure 1 presents the conceptual framework of the study. The variables were grouped as digital demographic characteristics, digital literacy, and mathematics academic performance.

Figure 1

Schematic Diagram Showing the Conceptual Framework of the Study



1.2. Objective of the Study.

The purpose of this study was to assess the digital demographics, digital literacy, and mathematics academic performance of students majoring in mathematics. It investigated the interrelationships of the variables further. Specifically, to establish the best model that describes the relationship among the variables studied.

2. Methods.

2.1. Research Design.

The research was quantitative in nature, following descriptive and predictive-correlational research designs which were used to possibly explain, establish, and examine the relationships between the variables under investigation. Similarly, this type of research allowed the study to explain or predict the variance of the dependent variable based on the variability of another variable.

2.2. Respondents of the Study.

The respondents of the study were the undergraduate first-year, second-year, and third-year mathematics major students of the university and its five external campuses under study in Eastern Visayas region of the Philippines. The students were officially enrolled in the second semester of the academic year 2021–2022. Mathematics students were chosen since the main purpose of the study was to explore the extent of readiness, literacy, and skills in using digital technology while learning mathematics through online learning, especially among mathematics students in higher education institutions. Through the electronic student management system of the university, 594 students were identified to participate in the study with a random sample of 322 students answered the survey.

1.3. Research Instrument.

The researcher adapted the Self-Report Digital Literacies (SRDL) instrument (Peled et al., 2021; Peled, 2020), which gave detailed information on how students evaluated their digital literacy based on the Seven Domains of Digital Literacy (SDDL) covered by the SRDL tool. The

instrument was administered to the respondents through online survey using a Google Form. Particularly, the survey tool consisted of three parts. The first section asked information relating to the profile of the respondents. Meanwhile, the second section collected the information on the respondents' digital demographic characteristics. Finally, the third section contained questions that measured the respondents' level of digital literacy

1.4. Reliability and Validation of the Instrument.

Since the SRDL instrument was utilized in the Philippines, particularly in the Eastern Region, it was subjected to validation and reliability analyses to make it more specific to the student respondents' characteristics and locality. The face or expert and content validity have been evaluated first. During the validation process, the researcher invited four (4) experts to evaluate the tool's face and content validity. A dry-run of the updated tool was performed right after the validation process and the revisions based on expert suggestions and recommendations were done. Based on the results of the validation, the proposed seven (7) items for digital demographic characteristics were retained with minor revisions and determined to be content valid according to its relevance and clarity. Similarly, the 54 items for measuring digital literacy were retained with minor revisions on some of the elements, and four (4) items were recommended by experts to be added from the initial number of items, making it 58. The four items were added to the domains of information management and social responsibility, which each included two more items. Moreover, the revised digital literacy questionnaire yielded reliability levels for the seven subscales with alpha coefficients ranging from 0.805 to 0.949, which were found to have high reliability or internal consistency. Consequently, the updated survey tool version was reliable and valid.

1.5. Data Gathering Procedure.

Before starting data collection, the researcher ensured that all required protocols were followed, including submitting permission letters to the committee for the conduct of the study, obtaining approval for the research, and completing a hearing proposal. The researcher secured approval letters from key university personnel, to include campus directors, deans, department heads, and faculty members from the state university campuses where the study was conducted. The actual data gathering started on August 4, 2022 and concluded on August 24, 2022. Using a Google form, the survey was distributed online. The link was distributed to the mathematics professors and instructors of each campus who taught the target respondents' math classes. They distributed the link of the survey to the students' Facebook group chats.

In the first section of the questionnaire, the respondents were required to affirm that they read the Data Privacy Act and agreed to the researcher's use of their personal information and responses for research purposes. Equally, a student's consent to collect their mathematics grades for the first semester of Academic Year 2021–2022 was requested in the questionnaire. The students' grades were gathered using the survey link, in which the respondents entered their grades of the identified math courses according

to their grade level. At the end of the survey, the students were required to upload a screenshot of their grades from the university app or portal as a proof for the grades provided. The researcher included a statement detailing the purpose and significance of the survey, assuring the respondents that only themselves would have access to their responses and that their identities would remain completely anonymous.

1.6. Data Analysis.

To address the research objectives posed in the study and to test the research hypotheses, the collected data were analyzed using a variety of statistical techniques. Trial versions of IBM SPSS version 22 and IBM SPSS AMOS version 26 were utilized to conduct all of the essential analyses for the study. The percentage and frequency counts, mean and standard deviation were used to describe the digital demographics, digital literacy, and academic performance of the respondents. A regression and path analyses were performed to evaluate the models in terms of the direct and indirect impacts of the investigated variables.

2. Results and Discussions.

2.1. Digital Demographic Characteristics.

The study showed that in online learning, the majority of the students were using smartphones (83.9%), with internet connectivity through mobile data (67.7%), experiencing unstable internet access (72.1%), and spending an estimated monthly cost of internet at 50 to 999 pesos (82.9%). In addition, most students (54.0%) used both email and social media accounts for online learning communication; Google Meet video conferencing platform for online classes (98.8%); and both Facebook and Email/Google Classroom (37.0%) as electronic learning platforms for submission of class requirements, accessing class learning materials, receiving class announcement updates, and posting questions about online classes. Previous studies have corroborated the findings and argued that the difficulty of poor and unstable internet connectivity among students in online learning is strongly evident around the globe (Aboagye et al., 2021; Chung et al., 2020; Agormedah et al., 2020) and mainly in local contexts (Cleofas & Rocha, 2021). Similarly, the studies by Asio et al. (2021), Muthuprasad (2021) and Agormedah et al. (2020) revealed that smartphones were the most popular devices used by college and university students in attending online classes or courses. The use of Facebook as a social media platform utilized by the students to connect with their peers and develop a more productive form of communication in the collaborative educational process is consistent with the findings of the study of López-Meneses et al. (2020).

2.2. Digital Literacy of the Respondents.

Based on the results, the students have been reported to possess above-average levels of information research and retrieval literacy in online learning, with an overall mean of 4.0 (SD=0.5) and computed mean scores ranging from 3.6 to 4.2 in all literacy skill sets. Similarly, the students described their digital literacy as above-average for information validation (M=4.0), information processing (M=4.0), and team-based work (M=4.0). The students, on the other hand, were found to have an excellent level of digital literacies for information management (M=4.5), integrity awareness (M=4.5), and social responsibility (M=4.6). Moreover, the students indicated an excellent level of literacy for 3 out of 5 skill sets for information management, 10 out of 15 for integrity awareness, and all skill sets for social responsibility. The evidences showed in the study are consistent with those of Peled et al. (2021) and Zulkarnain et al. (2020), which suggested that students have a high level of information research and retrieval literacy. Furthermore, the findings that students have a high level of digital literacy in terms of managing online and offline information are comparable with those of Peled (2020) and Peled et al. (2021). The above-average and excellent levels on the different integrity awareness literacy skill sets are similar to the studies of Inan Karagul et al. (2021), and Peled (2020).

2.3. Level of Academic Performance of Respondents.

The findings showed that the large number of students, which was 64.6 %, exhibited superior academic performance in mathematics, gaining a mean GWA of 1.6. Following that, 25.8 % of the students displayed excellent performance, while only 0.6 % obtained a rating of 2.5 to 2.9. With a percent of variation of 15.8 %, the spread of the students' performance distribution around the mean was relatively acceptable.

2.4. Relationship Models among Variables.

A series of regression analyses established the digital demographic characteristics that significantly influenced digital literacy and mathematics academic achievement. Similarly, this study explored the characteristics associated with digital literacy that significantly affected or influenced mathematics academic performance. Path analysis showed the path model variables' direct, indirect, and total effects. The model's consistency was confirmed or validated by re-estimating the model using the same data set with 322 samples and including only the variables with significant indirect effects in the first estimated model.

3.4.1. Model Fit and Quality Indices.

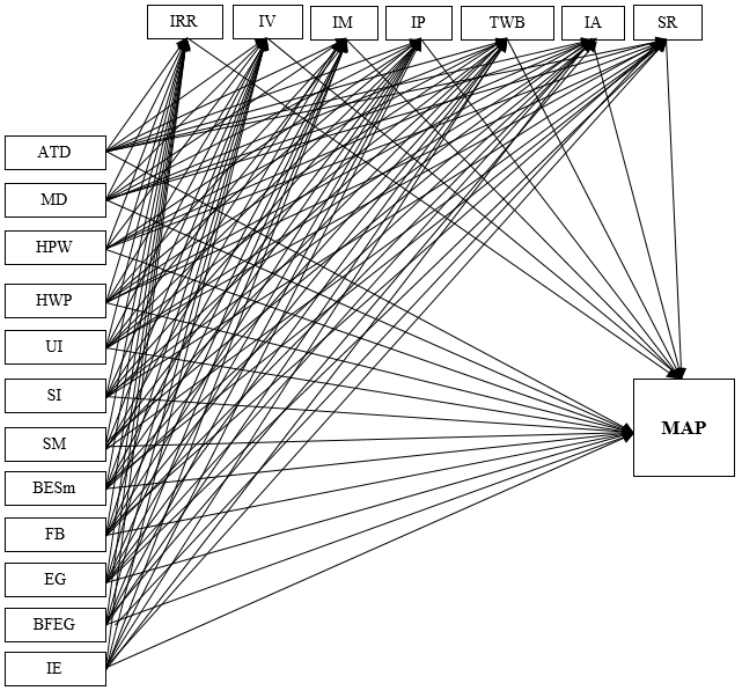
It was determined that the model fit the data adequately based on the computed indexes that measured the model's fitness and the data's quality: ⊠²/df = 2.48; *CFI* = 0.99; *TLI* = 0.90; *GFI* = 0.99; *NFI* = 0.99; *IFI* = 1.00; *RMSEA* = 0.07; and *RMR* = 0.04. According to Tabachnick and Fidell (2013) and Kline (2005), the relative chi-square value must be smaller than 5 in order for the model to be fit. Similarly, the estimated coefficients for CFI, TLI, and GFI must be more than 0.90 (Hair et al., 2010). To demonstrate an acceptable fit of the model to the data, the coefficients of RMSEA and SRMR must be less than 0.08 (Hair et al., 2010; Schumacker & Lomx, 2004), while the NFI and IFI values should be larger than 0.80. (Hair et al., 2010). This shows that the model can provide reasonable results for the study, which is a good indication that the analyses can be continued for the evaluation of the hypothesized relationship models among the investigated variables.

3.4.2. Hypothetical Path Structural Model.

Figure 2 shows the hypothesized path structural model of the study's relationships among the variables. Dummy variables were created for those categorical digital demographic characteristics, however, the video conferencing platform variable was excluded from the analysis due to the small number of cases in two of the three available categories. Among the digital demographic variables, the internet expenditure variable was the only scale variable.

Figure 2

The Hypothetical Structural Path Model



3.4.3. Coefficients of the Structural Path Model.

The succeeding discussions present the estimated path coefficients of the structural models for the relationship among digital demographic characteristics, digital literacy variables, and mathematics academic performance.

Table 1. Significant Effects of Digital Demographic Characteristics on Information Research and Retrieval Literacy.

Digital Demographic Characteristics	B	β	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-2.518	-0.161	1.037	0.015
[b] *Internet Connectivity Sources*				
Mobile data	0.378	0.031	1.090	0.727
Home Prepaid WiFi	-0.888	-0.050	1.357	0.513
Home WiFi Plan	-1.238	-0.065	1.567	0.433
[c]*Internet Connectivity Status*				
Unstable Internet	1.892	0.148	1.201	0.115
Slow Internet	-0.003	0.000	1.380	0.999
Internet Expenditure	0.000	-0.024	0.000	0.682
[d]*Social Account Used*				
Social Media	-0.696	-0.052	0.993	0.483
Both Email and Social Media	0.582	0.050	0.849	0.493
[e]*Electronic Learning Platform*				
Facebook	-0.865	-0.035	1.473	0.557
Email/Google Classroom	1.637	0.127	0.839	0.049
Both Facebook and Email/Google Classroom	0.508	0.043	0.809	0.531

***Notes*:** $R^2 = 0.412$; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); β(Standardized regression coefficients);

SE(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Information Research and Retrieval Literacy

According to the results, the use of a smartphone as the primary digital technology device for online learning (β=-0.16, *p*=0.015) and the use of Email/Google classroom (β=0.127, *p*=0.050) as an electronic learning platform showed a significant impact on the level of information research and retrieval literacy of the students. The negative unstandardized beta coefficients indicated that smartphone-only users have a 2.518 lower average level of information research and retrieval literacy than desktop/laptop and smartphone users (B=-2.518). Thus, the study suggests that using a smartphone alone yields a negative effect on performing skill sets related to information research and retrieval than using a smartphone and a desktop/laptop together. In addition, the students' exclusive usage of Email/Google Classroom as their primary electronic learning platform was favored to have a positive and statistically significant impact on informa-tion research and retrieval (β =0.127, *p*=0.049). The unstandardized beta path coefficient indica-ted that the students had a 1.637 higher mean level of information research and retrieval than the students who simultaneously used Facebook, Email/Google Classroom, and other learning platforms.

Table 2. Significant Effects of Digital Demographic Characteristics on Information Validation Literacy.

Digital Demographic Characteristics	B	*β*	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-0.984	-0.133	0.491	0.045
[b] *Internet Connectivity Sources*				
Mobile data	-0.747	-0.128	0.516	0.148
Home Prepaid WiFi	-1.236	-0.148	0.643	0.047
Home WiFi Plan	-1.255	-0.140	0.742	0.091
[c]*Internet Connectivity Status*				
Unstable Internet	-0.390	-0.064	0.569	0.493
Slow Internet	-1.030	-0.500	0.653	0.115
Internet Expenditure	0.000	-0.041	0.000	0.484
[d]*Social Account Used*				
Social Media	-0.515	-0.081	0.470	0.273
Both Email and Social Media	0.384	0.070	0.402	0.340
[e]*Electronic Learning Platform*				
Facebook	-0.141	0.012	0.698	0.840
Email/Google Classroom	0.842	0.138	0.397	0.034
Both Facebook and Email/Google Classroom	0.425	0.075	0.383	0.268

***Notes*:** R^2 = 0.214; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Information Validation Literacy

The level of digital literacy in completing skill sets linked to information and validation was significantly related to technology devices, internet connectivity at home, and electronic learning platform the students utilized during online learning. The single use of a smartphone (β = -0.133,

p=0.045) and connecting to the internet through home prepaid WiFi (⍰=-0.148, p=0.047) yielded negative and statistically significant effects on information validation literacy. The negative unstandardized beta coefficients indicated that the mean level of information validation literacy was 0.984 and 1.236 lower for students who only used a smartphone (B=-0.984) and home prepaid WiFi (B=-1.236) for online learning compared to those who use both desktop/laptop and smartphone and who connect to the internet via PisoNet. Likewise, the data found that using Facebook alone and utilizing both Facebook and Email/Google classroom together showed no significant statistical impact on information validation literacy. This suggests that the estimated mean difference of the students' levels of information validation literacy when using Facebook alone (B=-0.141) and Facebook and Email/Google Classroom together (B=0.425) in comparison to the practice of using Facebook, Email/Google classroom, and other learning platforms altogether is not statistically significant (p>0.05). On the other hand, the students' lone use of Email/Google classroom as their primary electronic learning platform exhibited a positive and statistically significant effect on their information validation literacy (⍰=0.138, p=0.034). The unstandardized beta path coefficient indicated that the students who only used Email/Google Classroom had a 0.842 greater mean level of data validation literacy than the mean score obtained by the students who used Facebook, Email/Google classroom, and other learning platforms jointly.

Table 3. Significant Effects of Digital Demographic Characteristics on Information Management Literacy.

Digital Demographic Characteristics	B	β	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-1.271	-0.178	0.469	0.007
[b] *Internet Connectivity Sources*				
Mobile data	0.121	0.021	0.494	0.807
Home Prepaid WiFi	-1.056	-0.131	0.614	0.085
Home WiFi Plan	-1.129	-0.131	0.709	0.111
[c]*Internet Connectivity Status*				
Unstable Internet	0.107	0.018	0.543	0.843
Slow Internet	-0.774	-0.116	0.624	0.215
Internet Expenditure	0.000	-0.069	0.000	0.237
[d]*Social Account Used*				
Social Media	0.268	0.043	0.449	0.551
Both Email and Social Media	0.584	0.111	0.384	0.128
[e]*Electronic Learning Platform*				
Facebook	-0.862	-0.076	0.666	0.196
Email/Google Classroom	0.610	0.102	0.379	0.926
Both Facebook and Email/Google Classroom	0.034	0.006	0.366	0.926

***Notes*:** R^2 = 0.335; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); β(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Information Management Literacy

Based on the analyses, only the availability of technological devices showed a significant impact on the students' level of information management literacy (=-0.178; p=0.007) out of the six (6) digital demographic variables. The negative unstandardized beta coefficients revealed that the students who use only smartphones for online learning have a level of information management literacy which mean was 1.271, lower than the students who used both smartphones and desktops/laptops (B=-1.271). This highlights the evident advantage of having a sufficient number of technological devices over those with a limited number of devices for completing skill sets related to information management for online learning. The results further indicate that internet expenses during online learning had shown no bearing on the students' self-reported level of information management literacy. The literacy levels of the students who connected to the internet using home prepaid WiFi, home WiFi plans, and mobile data were not significantly different from those who connected over PisoNet.

Table 4. Significant Effects of Digital Demographic Characteristics on Information Processing Literacy.

Digital Demographic Characteristics	B	β	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-1.556	-0.141	0.742	0.036
[b] *Internet Connectivity Sources*				
Mobile data	-0.380	-0.044	0.780	0.626
Home Prepaid WiFi	-0.220	-0.100	0.971	0.209
Home WiFi Plan	-1.782	-0.133	1.121	0.112
[c]*Internet Connectivity Status*				
Unstable Internet	0.413	0.046	0.859	0.631
Slow Internet	-0.458	-0.45	0.987	0.642
Internet Expenditure	0.000	-0.002	0.000	0.973
[d]*Social Account Used*				
Social Media	-0.093	-0.010	0.710	0.896
Both Email and Social Media	0.705	0.087	0.607	0.246
[e]*Electronic Learning Platform*				
Facebook	-0.034	-0.059	1.054	0.326
Email/Google Classroom	0.092	0.010	0.600	0.878
Both Facebook and Email/Google Classroom	-0.215	-0.026	0.579	0.710

***Notes*:** R^2 = 0.447; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); β(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Information Processing Literacy

The students' accessibility to technology devices for online learning illustrated a negative and statistically significant impact on their level of information processing literacy (=-0.141, p=0.036). The computed unstandardized beta coefficients revealed that the students who were solely using smartphones for online learning gained a level of digital literacy which mean was 1.556, lower than those who were using desktops/laptops and smartphones at the same time (B=-1.556). On the one hand, it was observed that the variables, such as internet connectivity sources, internet connectivity status, internet expenditure, social accounts used, and electronic learning platforms, were found to have no statistically significant impact on information processing literacy. This suggests that the students' self-reported levels of digital literacy on performing the skill sets relating to information processing were not varied when they were grouped according to internet connectivity access and status, social accounts, and electronic learning platforms.

Table 5. Significant Effects of Digital Demographic Characteristics on Team-Based Work Literacy.

Digital Demographic Characteristics	B	*β*	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-1.001	-0.084	0.810	0.215
[b] *Internet Connectivity Sources*				
Mobile data	-0.168	-0.018	0.852	0.844
Home Prepaid WiFi	-1.596	-0.118	1.060	0.132
Home WiFi Plan	-0.287	-0.020	1.218	0.814
[c]*Internet Connectivity Status*				
Unstable Internet	0.203	0.021	0.938	0.829
Slow Internet	-0.324	-0.029	1.078	0.764
Internet Expenditure	0.000	-0.044	0.009	0.462
[d]*Social Account Used*				
Social Media	-0.701	-0.068	0.776	0.366
Both Email and Social Media	-0.058	-0.007	0.664	0.930
[e]*Electronic Learning Platform*				
	-0.099	-0.005	1.151	0.932
	0.101	0.010	0.656	0.878
	0.089	0.010	0.633	0.889

***Notes*:** R^2 = 0.212; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Team-Based Work Literacy

The findings indicate that the availability of technological devices, the internet connectivity sources and status, the internet expenditure, the use of social accounts, and the electronic learning platform had shown negative and positive impacts on the level of team-based work among the students in an online learning environment. However, p-values greater than 0.05 suggested that these effects were not statistically significant. This means that the students' levels

of digital literacy were unaffected by the type of internet access they have at home, the status of their internet connection, the amount of money they spend for the internet, the type and number of social accounts they use for online learning communication, or the electronic learning platform they used.

Digital Demographic Characteristics	B	*β*	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-2.905	-0.161	1.201	0.016
[b] *Internet Connectivity Sources*				
Mobile data	0.266	0.019	1.262	0.833
Home Prepaid WiFi	-3.072	-0.151	1.575	0.045
Home WiFi Plan	-0.447	-0.020	1.814	0.805
[c]*Internet Connectivity Status*				
Unstable Internet	-0.254	-0.017	1.390	0.855
Slow Internet	-0.987	-0.059	1.597	0.536
Internet Expenditure	0.000	-0.009	0.000	0.877
[d]*Social Account Used*				
Social Media	0.312	0.020	1.149	0.786
Both Email and Social Media	1.576	0.118	0.983	0.109
[e]*Electronic Learning Platform*				
Facebook	0.932	0.032	1.705	0.585
Email/Google Classroom	1.513	0.102	0.971	0.119
Both Facebook and Email/Google Classroom	0.618	0.045	0.937	0.509

***Notes*:** R^2 = 0.399; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Integrity Awareness Literacy

The lone use of smartphones (β=-0.161, *p*=0.016) and connecting to the internet over prepaid WiFi at home (β=-0.151, *p*=0.045) had shown a negative and significant impact on the integrity awareness literacy level of the students. The unstandardized beta coefficients showed that the levels of integrity awareness literacy of the students which gained mean scores of 2.905 and 3.072 were lower compared to the levels of the students who only used a smartphone (B=-2.095) for online learning and who connected to the internet through home prepaid WiFi (B=-3.072), in comparison to the students who used a desktop/laptop and a smartphone altogether and connect to the internet through PisoNet. However, these estimated effects were statistically not significant. The other digital demographic variables, on the other hand, yielded a positive impact on the integrity awareness literacy of the students. This suggests that the students who used Facebook alone and social media and email simultaneously exhibited higher mean scores of 0.312 and 1.576, respectively, along with the levels of integrity awareness, compared to those who used social media, email, and SMS interchangeably.

Digital Demographic Characteristics	B	*β*	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	-0.506	-0.079	0.433	0.242
[b] *Internet Connectivity Sources*				
Mobile data	0.107	0.021	0.454	0.814
Home Prepaid WiFi	-0.796	-0.120	0.566	0.160
Home WiFi Plan	-0.205	-0.026	0.653	0.754
[c]*Internet Connectivity Status*				
Unstable Internet	-0.384	-0.073	0.501	0.443
Slow Internet	-0.337	-0.056	0.575	0.558
Internet Expenditure	0.000	0.029	0.000	0.622
[d]*Social Account Used*				
Social Media	0.573	0.103	0.414	0.166
Both Email and Social Media	0.741	0.156	0.354	0.036
[e]*Electronic Learning Platform*				
Facebook	0.271	0.026	0.614	0.659
Email/Google Classroom	0.505	0.095	0.350	0.149
Both Facebook and Email/Google Classroom	0.603	0.123	0.337	0.046

***Notes*:** $R^2 = 0.255$; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Social Responsibility Literacy

Using email and social media (⍰=-0.156, *p*=0.036) for online learning communication, as well as Facebook and Email/Google classroom (⍰=0.123, *p*=0.046), as the main electronic learning platforms for submitting class requirements, receiving updates from classes, and asking questions to professors, showed a positive and statistically significant impact on the level of social responsibility literacy among the students in an online learning environment. The computed unstandardized beta coefficients further suggested that, on average, students who used email and social media (B=0.741) as social accounts and Facebook and Email/Google classroom (B=0.603) together as electronic learning platform obtained a higher level of social sense of responsibility for online learning than the students who used email, social media, and SMS simultaneously as social accounts and Facebook and Email/Google classroom as electronic learning platforms. Based on the findings reported, these results were consistent and confirmed the findings of previous studies (Yustika & Iswati, 2020; López-Meneses et al., 2020; Peled et al., 2021; Peled, 2020).

Digital Demographic Characteristics	B	*β*	*SE*	*p*-value
[a]*Availability of Technology Devices*				
Smartphone	0.113	0.016	0.464	0.807
[b] *Internet Connectivity Sources*				
Mobile data	0.946	0.171	0.469	0.043
Home Prepaid WiFi	1.270	0.160	0.596	0.033
Home WiFi Plan	1.385	0.162	0.680	0.042
[c]*Internet Connectivity Status*				
Unstable Internet	0.386	0.067	0.517	0.455
Slow Internet	-0.289	-0.044	0.595	0.627
Internet Expenditure	0.000	0.000	0.033	0.555
[d]*Social Account Used*				
Social Media	0.366	0.060	0.428	0.392
Both Email and Social Media	0.595	0.114	0.370	0.108
[e]*Electronic Learning Platform*				
	0.355	0.031	0.634	0.576
	0.028	0.005	0.368	0.940
	-0.104	-0.019	0.349	0.767

***Notes*:** R^2 = 0.253; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Reference Categories**: [a]Using both Desktop/Laptop and Smartphone; [b]PisoNet Internet Source; [c]Fast/Stable Internet; [d]Using Email, Social Media, and SMS; [e]*Using Facebook, Email/Google Classroom, and Other Learning Platform*
Dependent Variable: Mathematics Academic Performance

Based on the findings, internet connectivity sources were found to have a positive and significant impact on the mathematics academic performance. It is interesting to note that the mathematics performance of the students who had access to mobile data yielded 0.946 higher mean score that the mathematics performance of the students who used PisoNet (B=0.946). Similar results were observed on the students who had Home Prepaid WiFi (B=1.270) and Home WiFi Plans (B=1.385), highlighting a higher mean of the level of mathematics academic performance of the students compared to those who were connected PisoNet. In addition, other digital demographic variables, including availability of technology devices, internet status, internet expenditure, social account use, and electronic learning platform, exhibited positive but not statistically significant effects on the mathematics academic performance (p>0.05). This implies that the students' mathematics academic performance in an online learning environment did not differ significantly in terms of technology devices used, internet status at home, amount of money spent on internet, social accounts used for online learning communication, and electronic learning platform used.

The findings of this study support previous research that found that a lack of internet access and poor internet connectivity had a statistically significant positive or negative impact on students' academic performance during online learning (Ben Youssef et al., 2022; Fatema et al., 2020; Barrios & Hochberg, 2020). Likewise, the study corroborated the findings of S. Yousef and K. Yousef (2022), in which the influence of social media use, such as Facebook and email, on academic performance was not statistically significant. The statistically significant and positive or negative effects of computers and laptops on online learning during a pandemic on students'

academic progress were consistent with previous studies (Ben Youssef et al., 2022; Yustika & Iswati, 2020).

Table 9. Significant Effects of Digital Literacy on Mathematics Academic Performance.

Digital Literacy Variable	B	*β*	*SE*	*p*-value
Information Research and Retrieval	0.099	0.224	0.024	<0.001
Information Validation	0.180	0.206	0.050	<0.001
Information Management	0.169	0.175	0.053	0.001
Information Processing	0.025	0.040	0.033	0.446
Team-Based Work	-0.009	-0.015	0.031	0.771
Integrity Awareness	0.027	0.070	0.021	0.183
Social Responsibility	-0.020	-0.018	0.057	0.726

***Notes*:** $R^2 = 0.453$; The path is significant at the 0.05 level
B(Unstandardized regression coefficients); *β*(Standardized regression coefficients); *SE*(Standard Errors); **Dependent Variable**: Mathematics Academic Performance

Based on the findings, the level of digital literacy demonstrated by the students in relation to information research and retrieval (=0.221, $p<0.001$), information validation (=0.206, $p<0.001$), and information management (=0.175, $p=0.001$) showed a positive and significant impact on their mathematics academic performance. The positive beta coefficients between the paths of information research and retrieval and the academic performance implied an increase in information research and retrieval literacy which led to an increase of the academic performance, and vice versa. Equally, the positive beta coefficients between the paths of the information validation and the academic performance so do with the information management and the academic performance suggested that the level of information validation and management literacy had a positive effect on the students' mathematics grades; hence, the increase in digital literacy led to better academic performance in an online learning environment. This study confirms the findings of Moscoso-Paucarchuco et al. (2022), Mehrvarz et al. (2021) on the significant impact of digital literacy on the academic performance of the students in online learning. Likewise, the present study yielded comparable results, which support the findings that academic performance was significantly and negatively linked with the students' level of digital literacy as related to digital creation, information validation, and information management (Ben Youssef et al., 2022; Limnious et al., 2021).

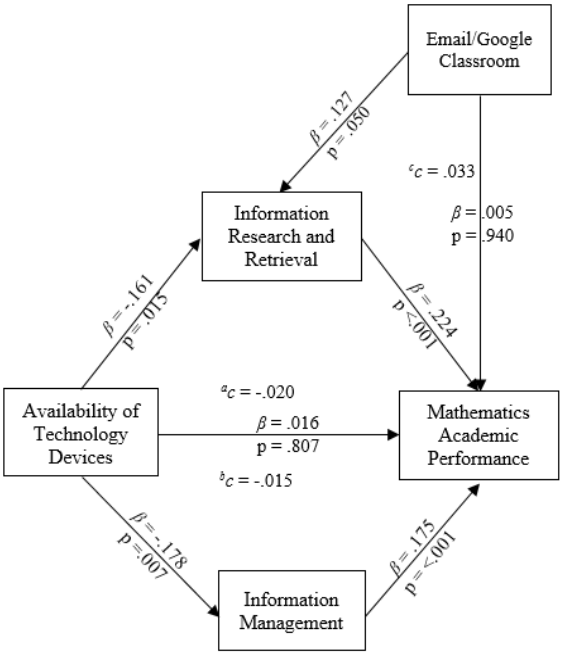
3.4.4. Indirect Effects in the First Model

The analyses present the significant indirect effects of the path model. The findings showed that the indirect effects of information research and retrieval literacy on the relationship between availability of technology devices and mathematics academic performance (=-0.036, $p=0.036$), as well as Email/Google Classroom and mathematics academic performance (=0.028, $p=0.050$), were found to be statistically significant. This suggests that the students' level of information research and retrieval literacy completely mediated or indirectly influenced the relationships between availability of technology devices and mathematics academic performance and Email/Google Classroom and mathematics academic performance in online learning.

Likewise, information management literacy significantly mediated the relationship between the availability of technology devices and the mathematics academic performance (⍰=-0.031, *p*=0.039). The data indicates that the students' level of information research and retrieval literacy statistically explained the significant impact of technology devices and Email/Google classroom on their mathematics academic performance in online learning. Using a smartphone exclusively indicated a negative impact on the level of information research and retrieval (⍰ =-0.161, *p*=0.015), which means that the students who used both desktop/laptop and smartphone at the same time gained positive mathematics academic performance (⍰ =0.224, *p*<0.001). The use of Email/Google classroom as electronic learning platforms positively affected information research and retrieval (⍰=0.127, *p*=0.050) which in turn yielded positive effect on the students' academic performance.

Figure 3

Significant Indirect Effects of the Path Model with Coefficients



3.4.5. Model Validation

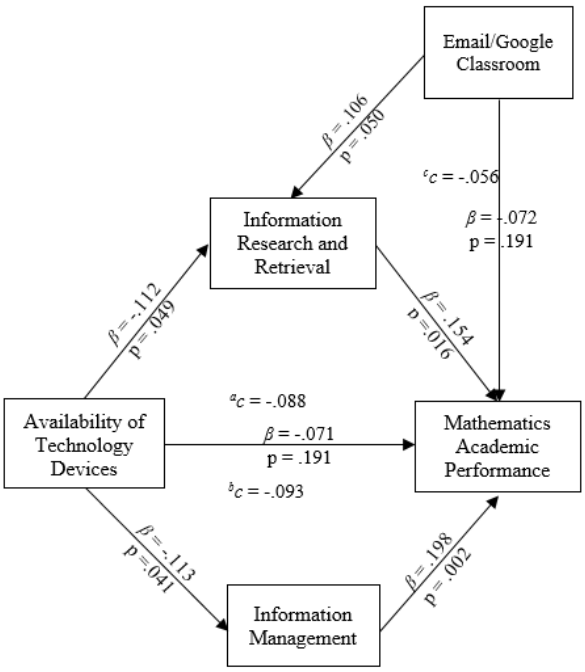
The succeeding presentations highlighted the findings of re-evaluating the derived path model illustrated in Figure 3 using the same data set of 322 samples, but this time including only the variables with significant indirect effects to validate the model's data fitness. The computed indices used to assess data-model fit for re-evaluation of the model were acceptable (⍰²/df = 2.91; *CFI* = 0.99; *TLI* = 0.99; *GFI* = 0.99; *NFI* = 0.98; *IFI* = 0.99; *RMSEA* = 0.04; and *RMR* = 0.05). Thus, the model may provide reasonable estimates of variables, which are supported by and match the previous path model's fit data indices.

It can be gleaned in figure 4 that the estimated indirect effects of variables in the path model. The model indicates that the indirect effects of information research and retrieval (⍰=-0.017, *p*=0.047) and information management (⍰=-0.022, *p*=0.047) on the relationships between the availability of technology devices and the mathematics academic performance were statistically significant. This suggests that the effects of technological devices use on academic performance in online learning was statistically explained or mediated by the students' level of digital literacy in information search and retrieval and information management. On the other hand, the estimated indirect effects of information research and retrieval on the relationship between Email/Google classroom and mathematics academic performance yielded contras-

ting results from the previous path model (*see* Figure 3) which showed no statistical significance. This suggests that the students' level of digital literacy in terms of performing skill sets related to information research and retrieval (=0.016, p=0.078) did not have a significant effect on how well students' performed in mathematic in online learning when they used Email or Google Classroom as an electronic learning platform to turn in class assignments, get updates from professors, and find out about school updates.

Figure 4

Significant Indirect Effects of the Path Model with Coefficients



The two models highlighted the consistency of the digital literacy variables, specifically information research and retrieval and information management, as significant mediators or intervening variables in explaining the significant impact of technology device availability on the mathematics academic performance in online learning. The indirect effect of information research and retrieval as a mediator-variable between the relationships of Email/Google classroom and mathematics academic achievement, which was found to be significant in the first model, was not significant in the second model.

3. CONCLUSIONS.

Based on the study's findings, it is concluded that students reported having limited access to technology devices, poor internet access, and unstable internet status, which described their overall online learning condition. This has resulted in the popularity of Google Meet for synchronous classes, which consumes less data than other video conferencing platforms, as well as Facebook and email for online learning communication and as an electronic learning platform for submitting class works, receiving school announcement updates, and posting questions to professors.

Digital demographic characteristics and digital literacy have significant effects on students' mathematics academic performance. Similarly, the digital demographic characteristics of students have a significant effect on their digital literacy. These results highlight how important it is for students to have access to technology devices, ways to connect to the internet, social

accounts, and e-learning platforms, all of which affect how well they perform with research and retrieval, information validation, information management, information processing, awareness of integrity, and social responsibility. The results further showed that there is no significant relationship between the money students spend on the internet monthly and the quality of their internet connection in relation to their level of digital literacy. Students who depend on prepaid Wi-Fi for internet access at home exhibit a lower level of literacy in information validation and integrity awareness compared to those who use PisoNet.

Additionally, students who exclusively use smartphones for online learning demonstrate lower levels of digital literacy in various skill sets, including information research and retrieval, information validation, information management, information processing, integrity awareness, and social responsibility, when compared to students who have access to both smartphones and desktops/laptops. Conversely, students who exclusively rely on email and social media for online communication have a higher level of social responsibility compared to those who use email, social media, and SMS simultaneously. Students who exclusively access Facebook and Email/Google Classroom as their electronic learning platform demonstrate a superior level of competence in information research and retrieval literacy, information validation literacy, and a heightened sense of social responsibility compared to those who concurrently employ Facebook, Email/Google Classroom, and other learning platforms. The study found a strong and significant relationship between students' access to the internet and their performance in mathematics.

In both models demonstrating the significance of indirect effects, the level of information research and retrieval and information management literacy consistently and significantly influenced the relationship between the availability of digital devices and mathematics academic performance. Digital literacy in terms of information research and retrieval had significant indirect effects on the association between email and Google Classroom use and mathematics academic performance in the first model, but not in the second. The entirety of the results clearly showed the significance of digital technology resources and digital literacy for students' academic success when attending online learning.

4. Recommendations and Future Direction.

The study recommends that the university may perform an initial assessment of students' digital attributes, such as ownership of technological devices and access to the internet, to identify those who do not have the necessary resources to engage in online learning. Subsequently, a program should be developed to support these students. The university may offer students alternative options for submitting course requirements to accommodate those with limited internet connectivity and technological devices. The student's proficiency in digital literacy across various identified domains can be further improved, as it has been identified as a significant determinant of their success in online education. Moreover, the study promotes significant awareness among parents and guardians about the digital technological competencies that students currently possess, as well as the areas that need improvement in order to enhance their academic achievements.

The study could also be replicated in other research environments to refute or validate its findings, and the study's sample size could be expanded to include students from various disciplines and academic levels, rather than just mathematics education students. Likewise, it is recommended to incorporate other variables, such as institutional and teacher-related factors, into future research. These factors may have an impact on students' digital literacy and academic achievements in online learning. Additionally, it may be beneficial to explore future research using qualitative or mixed research methods. Lastly, it is recommended that the generated model be applied to different groups of mathematics major students in future studies to confirm or further validate the model's overall consistency.

Study Limitations.

1. The study is limited to measuring only the students' digital profile, academic performance in mathematics major courses, and their self-assessed digital literacy. Additionally, the study concentrates on modeling the interrelationship among these variables.

2. The study is limited to student respondents who are majoring in mathematics education at both the main and external campuses of the Eastern Visayas State University, Philippines.

3. The study covered students in their first to third year of study, while notably excluding fourth-year or senior mathematics students.

4. The study was carried out during the first semester of the academic year 2022-2023.

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