Analysing Undergraduates' Numeracy and Digital Proficiencies

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Abstract: The interplay between digital and numeracy skills is becoming more crucial in the evolving job market of the 21st century. Nonetheless, more research is required to understand the relationship thoroughly. The current study aims to examine the role of numeracy skills on university students' digital skills. A quantitative deductive approach was used by distributing questionnaires to collect data from respondents. A total of 600 questionnaires were disseminated, with 439 completed questionnaires employed for data analysis. The findings consistently revealed that students rated their personal numeracy and digital skills as highly proficient. A significant relationship emerged between numeracy skills and digital proficiency across diverse academic backgrounds and disciplines. The results also demonstrated a significant association between students' faculties and numeracy skills. However, no significant relationships were found between (i) faculties and the levels of digital skills, (ii) numeracy skills and different semesters, and (iii) digital skills and different semesters. In summary, the findings underscored the interdependence of digital and numeracy skills as a solid foundation for establishing numeracy skills to enhance digital capabilities. This study suggests incorporating numeracy skill advancement modules into relevant university courses, as this skill significantly contributes to mastering digital skills.

Keywords: Digital Skills, Logical Thinking, Numeracy Skills, Quantitative Reasoning

1. Introduction

The acquisition of numeracy skills and digital competence is key to achieving success in several domains, including professional and personal endeavours, in the dynamic landscape of the 21st century. The existing literature highlights that globalisation and technological advancements have transformed conventional business operations, wherein well-educated and skilled workforces with quantitative information processing skills beyond reading and writing abilities are highly required. Quantitative information skills are highly demanded to perform crucial decisions and resolve major issues (Wilkins, 2016), which are also key cognitive and workplace skills in the following decades (Jonas, 2018). Therefore, recognising the importance of quantitative information processing skills is pivotal for individuals' success in the 21st century (Lee-Post, 2019). According to the Programme for the International Assessment of Adult Competencies, numeracy is the ability to obtain, utilise, interpret, and communicate mathematical information and ideas while engaging in and managing the mathematical demands of a wide range of adult life circumstances (PIAAC, n.d.). Hence, numeracy skills are fundamental to the functioning of future data-driven and technologically sophisticated civilisations.

Digital talents are highly critical to the professional domain and all life aspects. A recent study (Hong et al., 2020) propounded that numeracy, reading or writing, and financial literacy are vital skills enabling individuals' active contribution towards society, which would allow individuals to resolve personal financial issues, such as budgeting and loans. Numeracy also assists individuals in performing more appropriate judgements and decisions in crucial life aspects by accurately comprehending, analysing, and retrieving relevant data (numeracy skills) via various technological interfaces (digital skills). Moreover, numeracy skills are crucial for effectively using information and communication technologies (ICT) with a sufficient level of understanding (Hong et al., 2020). Prijowuntato et al. (2023) contended that numeracy skills are essential to university students for more effective learning, wherein the latest technological advancements could transform the education delivery method. Additionally, digital technologies increase the accessibility of learning materials through the Internet. Hong et al. (2020) postulated that individuals with higher mathematical skills would exhibit higher frequencies of Internet use. Students would also improve personal numeracy skills to adopt the latest digital educational technologies.

The need for educators and students to possess digital literacy skills arises from the widespread usage of e-learning platforms and digital classrooms. Thoroughly understanding data analytics is vital for obtaining a sound understanding of operational systems. Educators could implement student performance measures to ensure the development of educational methods that include both numeracy and digital skills. Previous studies also emphasised that both numeracy and digital skills are crucial for students across all disciplines before entering the job market (Delport, 2019). The skills should not be considered as additional skills. Instead, numeracy and digital skills are integral to graduates' ability to learn curricula effectively and apply their knowledge in the real world. Simultaneously, assessing students' numeracy skills is vital for educators to create suitable learning outcomes, activities, and assessments that facilitate numeracy and digital skills (Dalim et al., 2023). The increasing global interconnection facilitated by digital technologies would migrate a substantial portion of conversations to online environments. Thus, a thorough comprehension of digital etiquette, security measures, and proficient online communication is pivotal, which underscores the importance of digital abilities.

Education is considered a crucial pathway for preparing a generation capable of addressing the complex challenges of the 21st century, with numeracy skills playing a vital role in equipping learners with the necessary abilities (Kuswanti, 2023). Past scholars (Kuswanti, 2023; Yang et al., 2022) reported that students' digital skills would positively impact knowledge, understanding, and skills of employing digital technologies as information sources, which highlighted the required efforts to advance students' digital skills (Zulkarnain et al., 2020). Accordingly, the present study incorporated numeracy skills as a predictor of students' digital skills. Concurrently, this study sought to determine the relationship between students' academic backgrounds and personal numeracy and digital skills. Furthermore, the current study examined the impact of numeracy skills on students' digital capabilities to provide insights into the interplay between the two skill sets within the higher educational context. The study aims to (i) investigate digital and numeracy skills among higher-education students with various academic backgrounds and disciplines, (ii) identify the relationship between students' academic backgrounds in terms of faculties and semesters and the levels of digital and numeracy skills, and (iii) examine the impact of numeracy skills on students' digital skills. The empirical evidence would enable educators and policymakers to develop appropriate interventions to improve students' numeracy and digital skills for a digitally integrated workplace in the 21st century.

2. Literature Review

2.1 Numeracy Skills

Numeracy skills are crucial to contemporary society characterised by technological advancements and high reliance on data-driven decision-making processes. The United Nations Educational, Scientific, and Cultural Organisation (UNESCO) defines numeracy as the ability to apply mathematical concepts to resolve issues and perform informed decisions, which is a skill set encompassing calculation, estimation, problem-solving, and data analysis. Numeracy comprises a diverse array of competencies, including the capacity to comprehend and utilise mathematical principles across different scenarios. It serves as a fundamental component of students' acquisition and utilisation of knowledge in practical circumstances (Sa'dijah et al., 2023). The significance of numeracy in terms of active social involvement and capitalising on possibilities from technological advancements was also highlighted by the Organisation for Economic Cooperation and Development (OECD). Yamashita et al. (2023) emphasised the significance of numeracy in both STEM occupations and daily life aspects, including managing personal finances and engagement in civic activities.

Sa'dijah et al. (2023) highlighted the growing importance of numeracy in global educational programmes and the need for students to apply mathematical principles in real-world scenarios. Similarly, it was emphasised that educators and students need to acquire a sound comprehension of mathematical ideas to facilitate the successful delivery of mathematics education (Kilpatrick et al., 2001). Educational institutions also play a significant role in imparting students with the necessary skills to thrive in future pursuits. Furthermore, Kim et al. (2016) discovered a significant correlation between numeracy skills and an individual's work performance in various domains, including calculation, estimation, problem-solving, and data analysis. Kars-Tietema and Kars (2018) asserted that incorporating real-world issues and technologies into mathematics education could equip students with the required skills to resolve future challenges. Therefore, numeracy is an integral aspect of comprehensive literacy, which assists in achieving success across disciplines, especially in higher education. Dalim et.al. (2023) proposed five components of numeracy skills, namely operation and calculation, quantitative reasoning and logical thinking, graphical representation, spatial visualisation and geometrical reasoning, and complex numbers (see Figure 1).

Figure 1

Numeracy Framework for Higher Education 2023

<table>
<tr><th colspan="3">NUMERACY SKILLS</th></tr>
<tr><td colspan="3">OPERATION AND CALCULATION
Basic math calculation, conversion, and answer</td></tr>
<tr><td>GRAPHICAL REPRESENTATION
Convert numbers into graphs, interpret data in graphical forms, in diagrams, interpret data in tables, solve a wide range of math problems</td><td>QUANTITATIVE REASONING & LOGICAL THINKING
apply fundamental mathematical concepts like algebra, convey mathematical information symbolically, visually, numerically, and verbally, interpret data, draw conclusions, apply mathematical/statistical concepts to predict and draw conclusions</td><td>SPATIAL VISUALISATION & GEOMETRIC REASONING
draw geometric figures in three dimensions, visualise three-dimensional (3D) objects easily, identify three-dimensional (3D) objects in different angles or positions</td></tr>
<tr><td colspan="3">COMPLEX NUMBER
use arithmetic methods, algebra, and geometrical methods to solve problems, solve complex numerical routines, and non-routine, using various means and strategies, describe, and compare geometric figures in two dimensions, can identify, describe, and compare geometric figures in three dimensions</td></tr>
</table>

2.2 Digital Competencies

The acquisition of digital skills is vital to graduates in maintaining relevance to society while effectively addressing future challenges (Audrin, & Audrin, 2022). The skills provide the younger generation with the necessary tools to fulfil the demands of the 21st century, which would enhance employment opportunities, increase productivity, and strengthen the capacity to adapt to the dynamic digital economy (van Laar et al., 2019; Eynon, 2021). Digital abilities encompass the aptitude to effectively manipulate and manage data by utilising digital tools, applications, and networks. Dalim et al. (2023) proposed a digital framework that includes five components, namely information literacy, computer and technology literacy, digital communication and collaboration skills, digital identity and well-being, and digital ethics. The digital skills are highly dependent on individuals' numeracy skills. Previous empirical evidence highlighted that numeracy skills positively impacted digital skills (Bernacki et al., 2021; Livingstone et al., 2023). Nonetheless, different academic disciplines require varying levels of critical thinking and digital skills from students. Previous studies (Duke et al., 2021; Supriyatno et al., 2020) have shown that social science students tend to demonstrate higher degrees of critical thinking, communication, and digital problem-solving skills, whereas humanities students typically exhibit greater creativity and proficiency in information processing. However, it is worth noting that creativity and information processing skills also significantly contributed to digital skill development (Vodă et al., 2022). Additionally, numeracy skills have been found to enhance efficiency in employing Internet services and ICT (Hong et al., 2020).

Figure 2

Digital Framework for Higher Education 2023

<table>
<tr><td colspan="3">INFORMATION LITERACY
find relevant, use, organise, elaborate, and manage digital information from different sources, distinguish different types of digital information and its purpose, process data into a more understandable form, reproduce and form new information, decide what to share, explore, develop new ideas/ project or opportunities, and showcase digital or artefact creation)</td></tr>
<tr><td rowspan="2">COMPUTER AND TECHNOLOGY LITERACY
ability to use and apply computer and software, create graphic design, adapt to learning preferences, and needs, organise, plan, and reflect learning, and knowledge on advanced digital</td><td>DIGITAL COMMUNICATION / COLLABORATION SKILL
convey ideas using multiple digital applications, build networking and collaboration using digital tools/platform</td><td rowspan="2">DIGITAL IDENTITY AND WELL BEING
impact of technology and digital activities, manage online and real-world interaction, the importance of maintaining physical and mental health</td></tr>
<tr><td>DIGITAL SKILLS</td></tr>
<tr><td colspan="3">DIGITAL ETHICS
acceptable online behavior including how to communicate and treat others, the credibility of the source and proper referencing, compliance with copyright issues, and privacy and security of personal information</td></tr>
</table>

3. Research Methodology

3.1 Research Design

This quantitative study employed a multi-phase approach to analyse the relationship between numeracy skills and digital skills among higher-education students from diverse academic backgrounds and disciplines.

3.2 Participants

The target sample size was 600 participants, which was more robust than previous studies with a sample size ranging from 55 to 400 respondents (Delport, 2019; Hoareau & Tazouti, 2023; Lee-Post, 2019; Lee & Choi, 2020; Rogowsky et al., 2018). The study recruited 439 participants with diverse academic backgrounds and disciplines from higher educational institutions. The faculties, colleges, and academies included the Faculty of Education, Academy of Language Studies, Academy of Contemporary Islamic Studies, College of Engineering Studies, College of Built Environment, College of Computing, Informatics and Media, Faculty of Accountancy, Faculty of Business and Management, Faculty of Applied Science, Faculty of Health Science, and Administrative Science and Policy Studies. The participants were recruited through a convenience sampling method. A structured questionnaire was utilised to gather information on students' digital and numeracy skills.

3.3 Instruments

Two major instruments were employed, namely a questionnaire on digital literacy and an assessment of numeracy skills. The questionnaire assessing digital competencies was derived from Dalim et al. (2023), which consisted of five distinct domains: information literacy, computer and technology literacy, digital communication and cooperation skills, digital identity and well-being, and digital ethics. The assessment of numeracy skills was based on Dalim et al.'s (2023) framework, which included evaluation of multiple cognitive abilities such as operation and calculation, quantitative reasoning and logical thinking, pictorial representation, spatial visualisation, geometrical reasoning, and complex numbers. The questionnaire was pre-tested before the actual data collection. A set of questionnaires was distributed to three academics for relevant feedback, and minor adjustments were subsequently performed based on their input before disseminating the final questionnaire to the participants.

3.4 Data Analysis

The initial phase involved preparing the data, identifying missing information, detecting unusual values, and verifying the normal distribution. Statistical analyses, such as descriptive statistics and chi-square tests, were conducted using the SPSS 26.0 software to summarise participant data and examine differences. This study also employed the SmartPLS 4.0 software to conduct structural equation modelling (SEM) to explore the relationship between digital and numeracy skills. The preliminary step involved conducting data screening and cleaning, which provided 439 final samples. Investigations on missing data, outlier detection, and univariate and multivariate normality tests were also conducted. The missing value analysis (MVA) conducted via the SPSS 26.0 software demonstrated no missing data. The univariate outliers were observed based on the extreme cases that appeared in the boxplots. Subsequently, the Mahalanobis Distant (D2) was utilised to determine multivariate outliers (Hair et al., 2010). The p-value of the Mahalanobis Distance for each of the 439 samples was computed and compared against the baseline value of $p < 0.001$. Any case with a p-value below 0.001 was excluded from the collected data. As a result, no univariate and multivariate outliers were observed. Subsequently, the skewness values of the 55 items ranged between - 2.346 and - 0.215, and the kurtosis value ranged between 0.004 and 6.590. The univariate normality of the collected data was achieved for all items, except for B1a, as the skewness values were within the threshold value of 1.0. The Mardia test for multivariate normality was conducted using the

Webpower software. Both skewness and kurtosis p-values were below 0.05, indicating a non-normal distribution of the data.

4. Analysis and Findings

4.1 Students' Profile

Figure 3 depicts student distribution by college, faculty, and academy. The Faculty of Education demonstrated the highest proportion, which accounted for 18.0% of the students, followed by the Academy of Language Studies (16.9%), Academy of Contemporary Islamic Studies (13.4%), College of Engineering Studies (5.2%), College of Built Environment (1.8%), College of Computing, Informatics, and Media (7.7%), Faculty of Accountancy (4.8%), Faculty of Business and Management (10.7%), Faculty of Applied Science (10.5%), Administrative Science and Policy Studies (5.9%), and Faculty of Health Science (5.0%). The distribution of students across different semesters is illustrated in Figure 2. The majority of the students were from Semester 3, which denoted the highest proportion (21.4%), followed by Semester 2 (19.4%), Semester 4 (18.9%), Semester 1 (15.3%), Semester 5 (11.8%), Semester 6 (10.7%), Semester 7 (1.6%), and Semester 8 (0.9%).

Figure 3

Students' Distribution by College/Faculty/Academy

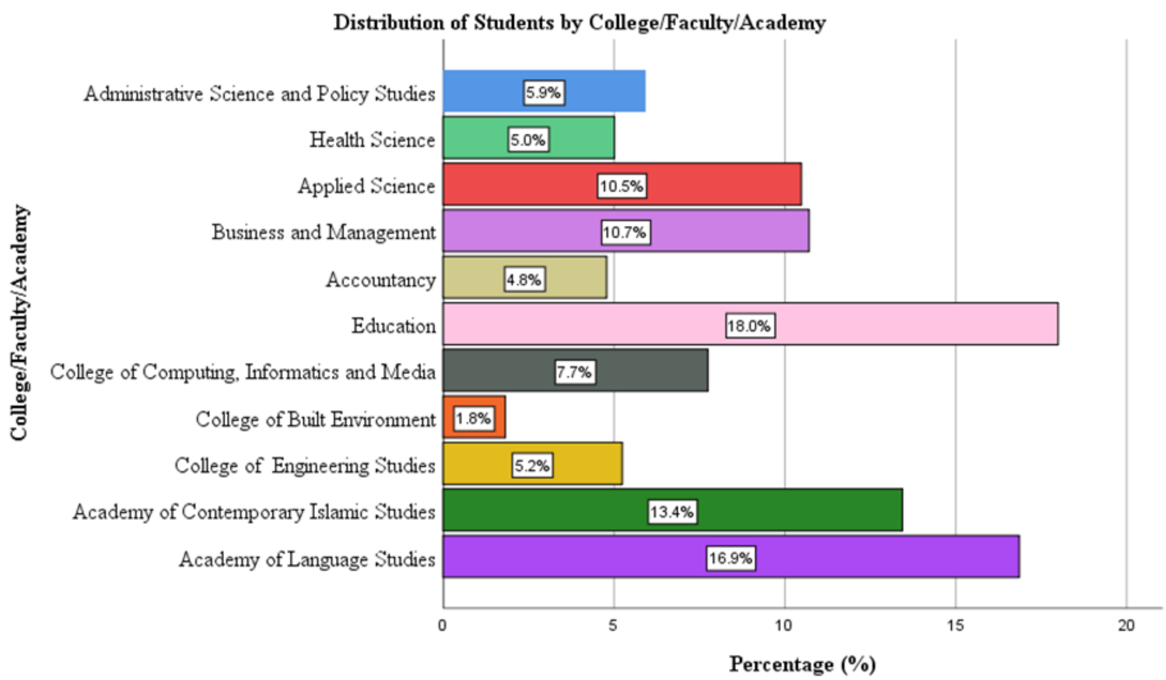
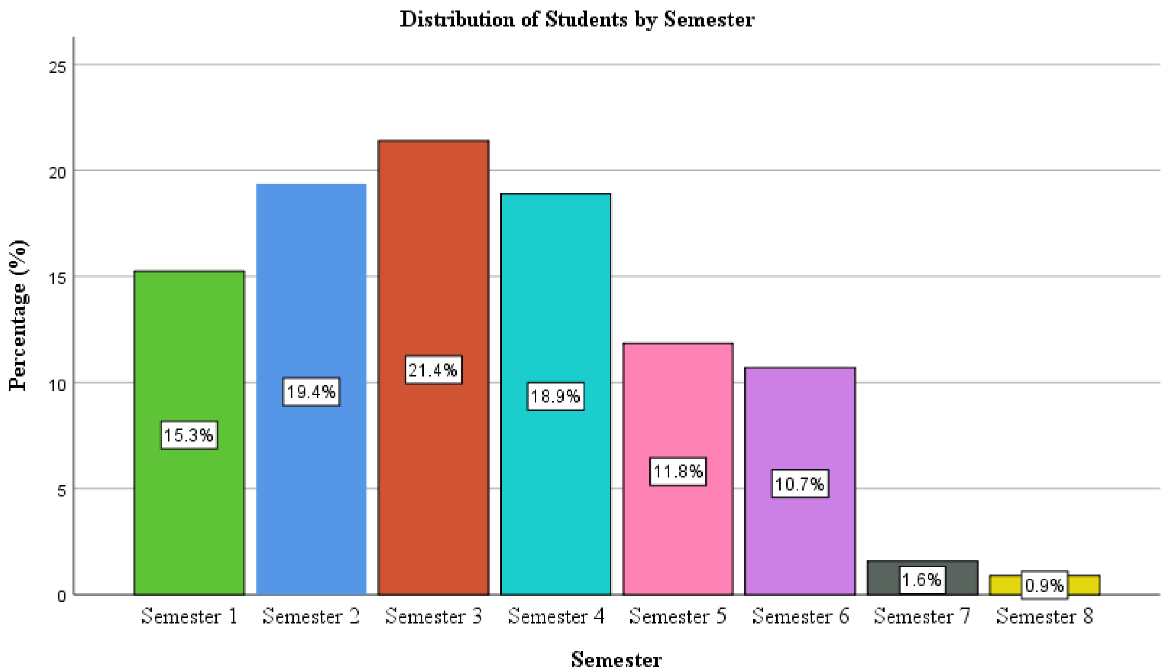


Figure 4

Students' Distribution by Semester



4.2 Digital Skills and Numeracy Skills among Higher Education Students with Various Academic Backgrounds and Disciplines

Table 1 shows the digital and numeracy skills-related items with descriptions, mean scores, standard deviations, and mean levels. The mean scores were categorised into three levels (low, moderate, and high) based on the cut-off score as suggested in Mohd Najib's (1999) study namely low (1.00 to 2.32), moderate (2.33 to 3.66), and high (3.67 to 5.0). For the digital skills, the mean score in this study was 4.11 with a standard deviation of 0.580, which indicated that the overall level of digital skills was high. Information literacy was also at a high level with a mean score of 4.12 and a standard deviation of 0.658. Table 1 illustrates that all components of digital skills, including computer and technological literacy, digital communication and collaboration skills, digital identity and well-being, and digital ethics achieved high levels. The mean values for all skills ranged from 3.92 to 4.28. For the numeracy skills, the mean score in the current study was 4.02 with a standard deviation of 0.637, which suggested that the level of numeracy skills was high. The mean value for all numeracy skills ranged between 3.65 and 4.51, except for the complex number (advanced concept), which was at the moderate level.

Table 1

Level of Skills

Item label	Description	Mean	Std. Deviation	Level of Mean
	Digital Skills			
C1a – C5d	Digital Skills	4.11	0.580	High
C1a – C1l	Information Literacy	4.12	0.658	High
C2a – C2e	Computer and Technology Literacy	3.92	0.746	High
C3a – C3d	Digital Communication / Collaboration Skill	4.02	0.733	High
C4a – C4c	Digital Identity and Well Being	4.28	0.692	High
C5a – C5d	Digital Ethics	4.27	0.704	High
	Numeracy Skills			
B1a – B5j	**Numeracy Skills**	**4.02**	**0.637**	**High**
B1a – B1g	Operation and Calculation	4.51	0.615	High
B2a – B2d	Graphical Representation	4.05	0.773	High
B3e – B3j	Quantitative Reasoning & Logical Thinking	3.82	0.758	High
B4a – B4e	Complex Number (Advanced Concept)	3.65	0.871	Moderate
B5f – B5j	Spatial Visualization & Geometric Reasoning	3.91	0.936	High

4.3 The Relationship between Students' Academic Backgrounds (Faculties and Semesters) and the Levels of Digital and Numeracy Skills

Table 2 portrays the distribution of students' numeracy skill levels according to the faculties, colleges, or academies, chi-square statistic, and p-value. Specifically, a significant relationship existed between students' faculties and the levels of numeracy skills at a 5% significance level ($\chi^2 = 22.32$, $p = 0.014$). The frequency and percentage represented the distribution of students within each faculty with low, moderate, and high numeracy skills, respectively. Students from the Academy of Language Studies represented the highest proportion (27.4%) in the "low and moderate" level of numeracy skills, while those from the Faculty of Education demonstrated the highest proportion (19.6%) in the "high" level of numeracy skills. Meanwhile, Table 3 depicts the distribution of students' digital skill levels according to the faculties, colleges, or academies, chi-square statistic, and p-value. The findings revealed an insignificant association between students' faculties and the levels of digital skills at a 5% significance level ($\chi^2 = 16.289$, $p = 0.092$). The frequency and percentage represented the distribution of students within each faculty with low, moderate, and high numeracy skills. Students from the Academy of Contemporary Islamic Studies demonstrated the highest proportion (19.3%) in the "low and moderate" level of digital skills, whereas students from the Faculty of Education represented the highest proportion (19.4%) in the "high" level of numeracy skills. The difference in digital skill levels was minimal among students, hence yielding an insignificant result.

Table 2

Relationship of students' faculty with their level of numeracy skills

Faculty/College/Academy	Level of numeracy skills		Chi-square, X^2	p-value
	Low & Moderate	High		
Academy of Language Studies	31 **27.4%**	43 13.2%	22.32	0.014*
Academy of Contemporary Islamic Studies	18 15.9%	41 12.6%		
College of Engineering Studies	3 2.7%	20 6.1%		
College of Built Environment	4 3.5%	4 1.2%		
College of Computing, Informatics and Media	8 7.1%	26 8.0%		
Education	15 13.3%	64 **19.6%**		
Accountancy	6 5.3%	15 4.6%		
Business and Management	8 7.1%	39 12.0%		
Applied Science	7 6.2%	39 12.0%		
Health Science	7 6.2%	15 4.6%		
Administrative Science and Policy Studies	6 5.3%	20 6.1%		

*Significant at 5% level (0.05)

Table 3

Relationship of students' faculty with their level of digital skills

Faculty/College/Academy	Level of digital skills		Chi-square, X^2	p-value
	Low & Moderate	High		
Academy of Language Studies	15 17.0%	59 16.8%	16.289	0.092
Academy of Contemporary Islamic Studies	**17** **19.3%**	42 12.0%		
College of Engineering Studies	2 2.3%	21 6.0%		
College of Built Environment	4 4.5%	4 1.1%		
College of Computing, Informatics and Media	5 5.7%	29 8.3%		
Education	11 12.5%	**68** **19.4%**		
Accountancy	7 8.0%	14 4.0%		
Business and Management	6 6.8%	41 11.7%		
Applied Science	10	36		

Faculty/College/Academy	Level of digital skills		Chi-square, X^2	p-value
	Low & Moderate	High		
	11.4%	10.3%		
Health Science	6 6.8%	16 4.6%		
Administrative Science and Policy Studies	5 5.7%	21 6.0%		

Table 4 presents the distribution of students' numeracy skills across different semesters, chi-square statistics, and corresponding p-values. The results demonstrated an insignificant association between students' semester and their level of numeracy skills at a 5% significance level (χ^2 = 8.129, p = 0.321). The frequency and percentage represented the distribution of students across semesters with low, moderate, and high numeracy skills. Particularly, students in the first semester exhibited the highest proportion (22.1%) with low and moderate levels of numeracy skills. Comparatively, students in the third semester demonstrated high numeracy skills (21.8%). The difference between semesters was insignificant. Table 5 illustrates the distribution of students' digital skills across different semesters, the corresponding chi-square statistic, and the p-value. Specifically, no significant association existed between students' semesters and the levels of digital skills at a 5% significance level (χ^2 = 3.107, p = 0.875). The frequency and percentage represented the distribution of students across semesters with low, moderate, and high numeracy skills. Students in the second and third semesters demonstrated the highest proportion (21.6%) with low to moderate levels of digital skills. A total of 21.4% of the students in the third semester exhibited high digital skills, which indicated a minimal difference between semesters.

Table 4

Relationship of students' semester with their level of numeracy skills

Semester	Level of numeracy skills		Chi-square, X^2	p-value
	Low & Moderate	High		
Semester 1	**25** **22.1%**	42 12.9%	8.129	0.321
Semester 2	19 16.8%	66 20.2%		
Semester 3	23 20.4%	**71** **21.8%**		
Semester 4	18 15.9%	65 19.9%		
Semester 5	15 13.3%	37 11.3%		
Semester 6	12 10.6%	35 10.7%		
Semester 7	1 0.9%	6 1.8%		
Semester 8	0 0.0%	4 1.2%		

Table 5

Relationship of students' semester with their level of digital skills

Semester	Level of digital skills		Chi-square, X^2	p-value
	Low & Moderate	High		
Semester 1	16 18.2%	51 14.5%	3.107	0.875
Semester 2	**19** **21.6%**	66 18.8%		
Semester 3	**19** **21.6%**	**75** **21.4%**		
Semester 4	13 14.8%	70 19.9%		
Semester 5	10 11.4%	42 12.0%		
Semester 6	10 11.4%	37 10.5%		
Semester 7	1 1.1%	6 1.7%		
Semester 8	0 0.0%	4 1.1%		

4.4 The Impact of Numeracy Skills on Digital Skills among Higher Education Students with Various Academic Backgrounds and Disciplines

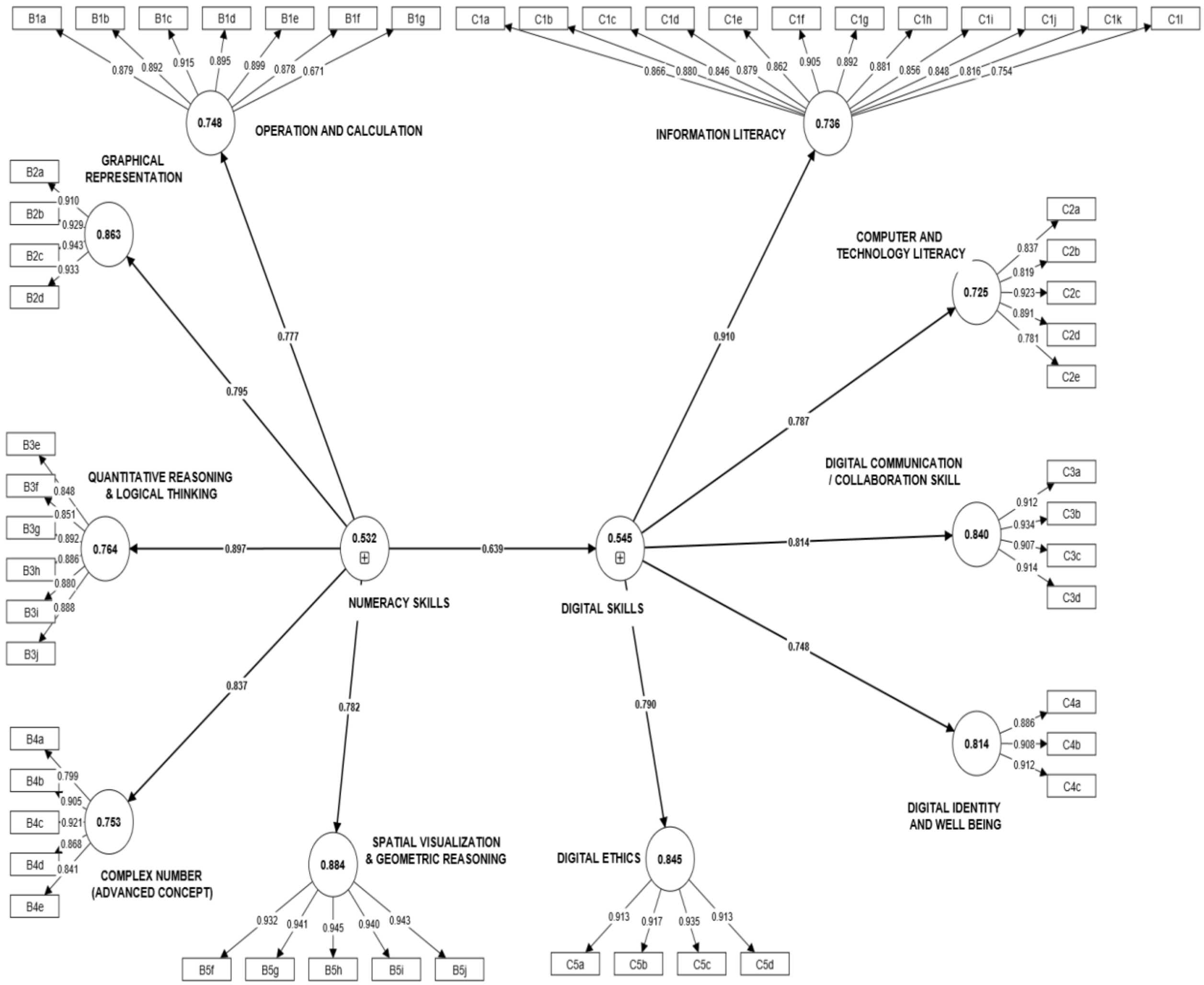
Partial least squares SEM (PLS-SEM) flexibly analyses multiple relationships among one or more sets of variables. The current study utilised PLS-SEM to predict digital competencies based on numeracy skills among students from diverse academic backgrounds and disciplines. The measurement model was assessed to examine the variable validity and reliability. Moreover, the structural model was appraised to investigate the relationships between the constructs. The analyses were performed through the SmartPLS 4 software.

4.5 Measurement Model Assessment

Measurement model assessment was conducted by adhering to Hair et al.'s (2014) recommendation. The measurement model or the outer model allows for evaluating the reliability and validity of items and constructs. The reliability results would demonstrate the stability and consistency of the measurement scale, while the validity findings would indicate the ability of a scale to represent the concept being measured (Hair et al., 2014). Figure 3 portrays the measurement model assessment results with all constructs specified as reflective. The PLS-SEM model includes higher-order constructs, in which the main constructs or second-order constructs are numeracy and digital skills. Meanwhile, the other constructs are first-order or sub-constructs.

Figure 3

The Measurement Model



4.6 Indicator Reliability, Construct Reliability, and Convergent Validity

The assessment of the measurement model involved evaluating indicator reliability, internal consistency, convergent validity, and discriminant validity. Hair et al. (2014) suggested that the outer loadings of items should be at least 0.5 to assess indicator reliability. This study achieved parsimonious unidimensionality when none of the items achieved low outer loadings (≥ 0.5). The composite reliability (CR) for all constructs also achieved values exceeding the threshold of 0.7, which indicated that all constructs contained internal consistency. In addition, convergent validity was adequate when each measurement item strongly correlated with the intended theoretical construct. Sufficient convergent validity was also achieved when the average variance extracted (AVE) value of a construct was at least 0.5 (Hair et al., 2014), wherein a construct explained over 50% of the variance among the scale indicators. All constructs achieved the minimum AVE threshold, thus postulating that the measurements for all constructs contained an acceptable level of convergent validity.

Table 6

Outer loading, AVE and CR values

Constructs	Sub-constructs	Item label	Outer loading (≥0.5)	AVE (≥0.5)	CR (≥0.7)
Numeracy Skills				0.670	0.910
	Operation and Calculation	-	0.777	0.748	0.954
		B1a	0.879		
		B1b	0.892		
		B1c	0.915		
		B1d	0.895		
		B1e	0.899		
		B1f	0.878		
		B1g	0.671		
	Graphical Representation	-	0.795	0.863	0.962
		B2a	0.910		
		B2b	0.929		
		B2c	0.943		
		B2d	0.933		
	Quantitative Reasoning and Logical Thinking	-	0.897	0.764	0.951
		B3e	0.848		
		B3f	0.851		
		B3g	0.892		
		B3h	0.886		
		B3i	0.880		
		B3j	0.888		
	Complex Number (Advanced Concept)	-	0.837	0.753	0.938
		B4a	0.799		
		B4b	0.905		
		B4c	0.921		
		B4d	0.868		
		B4e	0.841		
	Spatial Visualization and Geometric Reasoning	-	0.782	0.884	0.974
		B5f	0.932		
		B5g	0.941		
		B5h	0.945		
		B5i	0.940		
		B5j	0.943		
Digital Skills				0.659	0.906
	Information Literacy	-	0.910	0.736	0.971
		C1a	0.866		
		C1b	0.880		
		C1c	0.846		
		C1d	0.879		
		C1e	0.862		
		C1f	0.905		
		C1g	0.892		
		C1h	0.881		
		C1i	0.856		
		C1j	0.848		
		C1k	0.816		
		C1l	0.754		
Digital Skills	**Computer and Technology Literacy**	-	0.787	0.725	0.929
		C2a	0.837		

Constructs	Sub-constructs	Item label	Outer loading (≥0.5)	AVE (≥0.5)	CR (≥0.7)
		C2b	0.819		
		C2c	0.923		
		C2d	0.891		
		C2e	0.781		
	Digital Communication/ Collaboration Skill	-	0.814	0.840	0.955
		C3a	0.912		
		C3b	0.934		
		C3c	0.907		
		C3d	0.914		
	Digital Identity and Well Being	-	0.748	0.814	0.929
		C4a	0.886		
		C4b	0.908		
		C4c	0.912		
	Digital Ethics	-	0.790	0.845	0.956
		C5a	0.913		
		C5b	0.917		
		C5c	0.935		
		C5d	0.913		

4.7 Discriminant Validity

The final step of the reflective measurement model involved examining discriminant validity through the heterotrait-monotrait (HTMT) ratio of correlations (Hair et al., 2014). The HTMT ratio is the correlation mean of all indicators measuring different constructs relative to the average correlation value of indicators measuring the same construct. The HTMT approach is an estimate of the true correlation between two constructs when they are measured precisely or reliably. The true correlation also denotes a disattenuated correlation between two constructs, with a value close to 1 indicating a lack of discriminant validity. Discriminant validity would be established if the HTMT value is below 0.9. Tables 7 and 8 demonstrate that the HTMT values of the first and second-order constructs are below 0.9. Hence, the discriminant validity of the constructs is supported. Since all the measurement model criteria were met, the model achieved satisfactory reliability and validity requirements. Hence, the results fulfil the criteria to proceed with the structural model.

Table 7

HTMT values for first order constructs

	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
B1										
B2	0.625									
B3	0.624	0.721								
B4	0.516	0.568	0.837							
B5	0.486	0.532	0.627	0.680						
C1	0.425	0.565	0.601	0.469	0.434					
C2	0.414	0.535	0.532	0.485	0.466	0.644				
C3	0.392	0.534	0.481	0.367	0.486	0.651	0.728			
C4	0.404	0.464	0.449	0.331	0.433	0.593	0.582	0.627		
C5	0.417	0.461	0.430	0.328	0.402	0.621	0.560	0.651	0.789	

Note: B1-Operation and Calculation, B2-Graphical Representation, B3–Quantitative Reasoning and Logical Thinking, B4-Complex Number (Advanced Concept), B5-Spatial Visualization and Geometric Reasoning, C1-Information Literacy, C2-Computer and Technology Literacy, C3–Digital Communication/Collaboration Skill, C4–Digital Identity and Well Being, C5 – Digital Ethics

Table 8

HTMT values (second order constructs/main constructs)

	Digital skills	Numeracy skills
Digital skills		
Numeracy skills	0.659	

4.8 Structural Model Assessment

The structural model or the inner model reflects the relationships between the latent variables (Hair et al., 2014). The structural model was assessed by performing a bootstrap procedure with 5000 subsamples using the SmartPLS 4 software. The main focus in evaluating the structural model is to maximise the variance explained (R^2) for the endogenous latent construct and determine the size and significance of all path coefficients. Table 9 depicts the structural model assessment results. Specifically, a significant relationship existed between numeracy and digital skills (β = 0.639, t = 18.820, $p < 0.001$), thus, demonstrating a significant impact of numeracy skills on digital skills among higher education students with various academic backgrounds and disciplines. Furthermore, the R^2 value was 0.408 for digital skills, which posited that 40.8% of the total variance in students' digital skills could be explained and predicted by the students' numeracy skills. The effect size (f^2) value revealed a significant effect size (f^2 = 0.690) for numeracy skills. Meanwhile, the predictive relevance (Q^2) value measures the extent to which the model prediction is successful, with a Q^2 value below 0 confirming the presence of predictive relevance (Hair et al., 2014). Resultantly, the Q^2 value exceeded 0, which corroborated that the structural model achieved sufficient predictive relevance for the endogenous construct.

Table 9

Path Coefficients Result

Path	Beta	SD	T value	P-value	LCL	UCL	R^2	f^2	Q^2
Numeracy Skills -> Digital Skills	0.639	0.034	18.820	0.000***	0.566	0.699	0.408	0.690	0.404

***significant at 0.001 level, LCL=lower confidence level, UCL= upper confidence level.

5. Discussion

The present study sought to examine the impact of numeracy skills on students' digital skills while appraising the skill levels. The findings revealed that the students possessed adequate numeracy and digital skills, which affirmed that the institutions were preparing their students with the necessary skills for the 21st-century workplace challenges. The current study also assessed the impact of students' faculties on numeracy and digital skills. Specifically, faculties significantly influenced students' numeracy skills, which could be due to the positive learning environment. The findings were in line with previous studies, which discovered that mathematics could be effectively learnt by students if provided with adequate attention and conducive classroom environments (Hoyte, 2013). Contrarily, this study did not discover a significant impact of the faculty on the level of digital skills, which posited the difference in the academic disciplines and the focus of the subjects being taught. The university might also continue exploring the most optimal teaching method after education is transformed and digital technologies are widely integrated. Each discipline reflects its different culture regarding core areas and practices, which in turn influences the teaching methods and content delivered to students (Starkey et al., 2023).

The impact of the semester on both numeracy and digital skills was examined. Both relationships were insignificant as the academic discipline would influence the learning of numeracy and digital skills by the students (Starkey et al., 2023). For instance, a student studying in the medical discipline might not receive extensive training in numeracy and digital skills, as these areas are less relevant to the discipline. The study also investigated the impact of numeracy skills on students' digital skills through PLS-SEM. The results revealed that numeracy skills significantly influenced digital skills. The finding was consistent with previous studies, which demonstrated that students with higher numeracy skills tended to exhibit higher digital skills (Hong et al., 2020). In addition, students' skill levels were assessed. Students possessed diverse digital abilities and demonstrated the ability to identify pertinent digital information, recognise and apply digital tools, differentiate between various forms of digital information, process data, and collect information from diverse sources. An in-depth understanding of the appropriate timing and location to share information and the ability to employ digital tools for research and idea development were also recognised.

The students demonstrated a high level of proficiency in using computers, software programmes, and Internet services. Simultaneously, the students acknowledged the technological impact on physical, mental, social, and emotional well-being and exhibited adequate control of healthy online and offline interactions. The students were also aware of the most optimal practices for preserving physical and mental health when utilising digital technologies and demonstrated sufficient knowledge of digital ethics. In addition, the students demonstrated a high degree of operational and computation skills, high competencies in graphical representation, and adequate logical reasoning and quantitative reasoning. They asserted skilfulness in employing fundamental mathematical concepts, including algebra, interpreting data, drawing conclusions based on the provided data, applying mathematical and statistical concepts, and high ability in spatial visualisation and geometric reasoning. The findings propounded high proficiency in performing mathematical operations, graphically interpreting and representing data, applying mathematical concepts, and visualising geometric figures. Nevertheless, the proficiency level in complex numerical routines and non-routines, such as calculus or advanced calculus, was at a moderate level of competence.

6. Study Implications

The current study has significant implications, as it reveals a significant impact of numeracy skills on digital skills. This suggests that students with higher numeracy skills are likely to have higher levels of digital skills. The correlation underscores the importance of numeracy skills in acquiring and mastering digital competencies, which are aligned with a previous study reporting that mathematics education students from a state university in Tacloban City tended to exhibit higher levels of digital skills in social, mobile, operational, navigational, and creative aspects. The digital skills enabled the students to effectively employ digital tools and platforms for learning (Rabuya, 2023). Therefore, it is recommended to conduct numeracy skill advancement sessions that incorporate gamification techniques to successfully integrate digital technologies into education. A recent study contended that a web-based format for learning enables students to study independently at a personal pace, which not only supports the digital adoption journey but also enhances certain numeracy skills (Delport, 2019). Hence, numeracy skill advancement modules are recommended to be incorporated into relevant teaching sessions. Moreover, team-based learning methods could be employed for numeracy skill development among students. A recent study propounded that critical thinking and numeracy are integral factors in resolving complex challenges, wherein team-based learning potentially improves students' numeracy skills (Patricio, 2023).

7. Co-Author Contributions

The first author was responsible for the conceptualization, methodology, validation, formal analysis, investigation, resources, data curation, original draft writing, visualization, supervision, project administration, and funding acquisition. The second author contributed to the methodology, validation, formal analysis, investigation, and data curation. The third author was involved in reviewing and editing the manuscript. The fourth author handled the software and participated in validation, formal analysis, investigation, data curation, and original draft writing. The fifth author contributed to the reviewing and editing of the manuscript.

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9. Conclusion

The present study aimed to explore the levels of numeracy and digital skills among higher education students and determine the impact of students' academic backgrounds on the skills. The findings indicated that the students exhibited high levels of digital skills, including proficiency in information literacy, computer and technology literacy, digital communication and collaboration, digital identity and well-being, and digital ethics. Similarly, high proficiency was observed in numeracy skills, such as operation and calculation, graphical representation, quantitative reasoning, logical thinking, spatial visualisation, and geometric reasoning. Nonetheless, the proficiency in complex number domains was moderate, which indicated the improvement area. The investigation into the association between students' academic backgrounds (faculties and semesters) and skill levels revealed significant findings. A significant relationship existed between students' faculties and the levels of numeracy skills, which postulated that the faculty would significantly influence students' numeracy competencies. Nevertheless, no significant relationship was observed between students' faculties or semesters and the degrees of digital skills, which posited that digital skills were uniformly distributed across different faculties and academic phases, owing to the pervasive nature of digital technologies in all study fields.

10. References

Audrin, C., Audrin, B. (2022). Key factors in digital literacy in learning and education: a systematic literature review using text mining. Educ Inf Technol 27, 7395–7419. https://doi.org/10.1007/s10639-021-10832-5

Bernacki, M. L., Vosicka, L., Utz, J. C., & Warren, C. B. (2021). Effects of digital learning skill training on the academic performance of undergraduates in science and mathematics. *Journal of Educational Psychology*, *113*(6), 1107.

Dalim, S. F., Aris, S. R. S., Hoon, T. S., Nadzri, F. A., Deni, S. M., Yahya, N., & Si, E. M. (2023). Framework for Numeracy and Digital Skills Attributes in Higher Education. *Research in Social Sciences and Technology*, *8*(3), 16-35.

Delport, D. (2019). Numeracy students' perspectives on a new digital learning tool at a South African university. *South African Journal of Higher Education*, *33*(5), 25-41.

Duke, N. K., Halvorsen, A.-L., Strachan, S. L., Kim, J., & Konstantopoulos, S. (2021). Putting PjBL to the test: The impact of project-based learning on second graders' social studies and literacy learning and motivation in low-SES school settings. *American Educational Research Journal*, *58*(1), 160-200.

Eynon, R. (2021), Becoming digitally literate: Reinstating an educational lens to digital skills policies for adults. Br. Educ. Res. J., 47: 146-162. https://doi.org/10.1002/berj.3686

Hair Jr, J. F., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modelling (PLS-SEM): An emerging tool in business research. *European Business Review*, *26*(2), 106-121.

Hair, J., F., Black, W. C., Babin, B., J., Anderson, R., E. & Tatham R. L., (2010). Multivariate Data Analysis. (6th ed). New Jersey: Pearson Prentice Hall.

Hoareau, L., & Tazouti, Y. (2023). Effect of teachers' acceptance of an educational app on students' early literacy and early numeracy skills. *Education and Information Technologies*, 1-22.

Hong, J., Thakuriah, P. V., Mason, P., & Lido, C. (2020). The role of numeracy and financial literacy skills in the relationship between information and communication technology use and travel behaviour. *Travel Behaviour and Society*, *21*, 257-264.

Hoyte, J. (2013). Mathematics: Going beyond the academic discipline.

Jonas, N. (2018). Numeracy practices and numeracy skills among adults.

Kars-Tietema, M., & Kars, E. L. (2018). Preparing students for the future: The importance of numeracy skills in the 21st century. Journal of Education and Practice, 9(19), 128-133. https://doi.org/10.1080/00228958.2011.10516575

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics (Vol. 2101).* (National research council (ed.)). National Academy Press. https://nap.nationalacademies.org/read/9822/chapter/12

Kim, Y., Lee, J., & Lee, K. (2016). The role of numeracy in the prediction of job performance: A meta-analytic review. Journal of Educational Psychology, 108(2), 200–214. https://doi.org/10.1037/edu000009

Kuswanti, H. (2023). Strategy to improve student literacy and numeracy abilities. *Jurnal Scientia*, *12*(04), 2020-2025.

Lee, H. K., & Choi, A. (2020). Enhancing early numeracy skills with a tablet-based math game intervention: A study in Tanzania. *Educational technology research and development*, *68*, 3567-3585.

Lee-Post, A. (2019). Developing numeracy and problem-solving skills by overcoming learning bottlenecks. *Journal of Applied Research in Higher Education*, *11*(3), 398-414.

Livingstone, S., Mascheroni, G., & Stoilova, M. (2023). The outcomes of gaining digital skills for young people's lives and wellbeing: A systematic evidence review. *New media & society*, *25*(5), 1176-1202.

Mohamad Najib Abdul Ghaffar (1999). Penyelidikan Pendidikan. Johor: Penerbit Universiti Teknologi Malaysia.

Patricio, F. (2023). Implications of Team-Based Learning Strategies on the Attitude of Freshmen Students in Mathematics in a State University in Cagayan Valley, Philippines. *Psychology and Education: A Multidisciplinary Journal*, *9*(3), 276-294.

PIAAC. (n.d.). *he program for the international assessment of adult competencies*. National Center for Education Statistics, the Institute of Education Sciences. Retrieved 18th December from https://www-emerald-com.eserv.uum.edu.my/insight/content/doi/10.1108/JARHE-03-2018-0049/full/html#ref065

Prijowuntato, S. W., Widharyanto, B., & Julie, H. (2023). the Influence of Literacy and Numeracy Skills on the Success of College Students in the Faculty of Teacher Training and Education. *Jurnal Pendidikan Ilmu Sosial*, *32*(2), 173-188.

Rabuya, C. A. (2023). Digital Skills of Mathematics Education Students in a State University: Psychological Basis for an Action Plan. *Journal for ReAttach Therapy and Developmental Diversities*, *6*(9s), 444-454.

Rogowsky, B. A., Terwilliger, C. C., Young, C. A., & Kribbs, E. E. (2018). Playful learning with technology: the effect of computer-assisted instruction on literacy and numeracy skills of preschoolers. *International Journal of Play*, *7*(1), 60-80.

Sa'dijah, Cholis & Purnomo, Heri & Abdullah, Abdul & Permadi, Hendro & Anwar, Lathiful & Tejo dwi cahyowati, Ety & Sa'diyah, Mukhtamilatus. (2023). Students' numeracy skills in solving numeracy tasks: Analysis of students of junior high schools. AIP Conference Proceedings. 2569. 040011. 10.1063/5.0113664.

Starkey, L., Yates, A., de Roiste, M., Lundqvist, K., Ormond, A., Randal, J., & Sylvester, A. (2023). Each discipline is different: teacher capabilities for future-focussed digitally infused undergraduate programmes. *Educational technology research and development*, *71*(1), 117-136.

Supriyatno, T., Susilawati, S., & Hassan, A. (2020). E-learning development in improving students' critical thinking ability. *Cypriot Journal of Educational Sciences*, *15*(5), 1099-1106.

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2019). Determinants of 21st-century digital skills: A large-scale survey among working professionals. Computers in Human Behavior, 100, 93–104 https://doi.org/10.1016/j.chb.2019.06.017

Vodă, A. I., Cautisanu, C., Grădinaru, C., Tănăsescu, C., & de Moraes, G. H. S. M. (2022). Exploring digital literacy skills in social sciences and humanities students. *Sustainability*, *14*(5), 2483.

Wilkins, J. L. (2016). An assessment of the quantitative literacy of undergraduate students. *The Journal of Experimental Education*, *84*(4), 639-665.

Yang, X., Yan, M., Ruan, Y., Ku, S. Y. Y., Lo, J. C. M., Peng, P., & McBride, C. (2022). Relations among phonological processing skills and mathematics in children: A meta-analysis. *Journal of Educational Psychology*, *114*(2), 289.

Zulkarnain, Z., Heleni, S., & Thahir, M. (2020). Digital literacy skills of math students through e-learning in COVID-19 era: a case study in Universitas Riau. Journal of Physics: Conference Series,