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Investigating the Impact of ICT on Mathematics Performance Among Students in South-East Asian Countries: Insights From PISA 2018 Data*

Abstract. This study investigates the influence of Information and Communication Technology (ICT) on students' performance in mathematics across six South-East Asian countries, utilizing the Programme for International Student Assessment (PISA) data. The research focuses on data from the 2018 PISA wave and includes six countries: Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore, and Thailand. A multivariate linear regression analysis reveals that several factors significantly impact mathematics achievement, including economic, social, and cultural status (ESCS); the proportion of female students; and ICT-related variables such as computer availability and internet connectivity. Results indicate that higher ESCS and a greater proportion of female students correlate positively with higher PISA mathematics scores. The findings suggest that enhancing ICT resources in schools, as well as improving ICT-related home possessions, can lead to better educational outcomes in mathematics. This research highlights the critical role of ICT in fostering academic achievement and calls for policies that prioritize ICT integration in education.

1. Introduction

Information and Communication Technology (ICT) broadly encompasses technologies such as radio, telephone, video, television, computers, and associated services, which are utilized to create, store, share, transmit, manage, and analyze information (Tinio, 2003). The global impact of ICT is profound; nations' development is often closely linked to their level of ICT advancement (Al-araibi et al., 2019). In today's increasingly digital world, ICT has revolutionized various sectors, particularly education. Governments and educational institutions worldwide are investing heavily in ICT tools to enhance learning outcomes and better prepare

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students for the digital economy (Amin, 2019). The integration of ICT in education has grown rapidly, with many countries making significant investments in ICT infrastructure. These investments are driven by four key objectives: supporting economic growth, promoting social development, advancing education reform, and enhancing educational management and accountability (Kozma, 2008).

In conjunction with the rise of ICT, international large-scale assessments have emerged as vital resources for educational researchers. These assessments provide extensive databases containing diverse information, including students' performance, backgrounds, and school practices. Among these, the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD), has significantly influenced educational research development (OECD, 2019). PISA evaluates the literacy of 15-year-old students in reading, mathematics, and science every three years, while also assessing cross-curricular competencies, such as collaborative problem-solving skills. This assessment is designed to measure students' ability to apply functional skills as they approach the end of their compulsory education.

The influence of PISA extends beyond assessment results; its reports and analyses are crucial in shaping educational policies. Typically, released after each assessment cycle, these analyses provide essential insights into educational practices (Wiseman, 2013). However, the depth of the PISA database offers ample opportunities for further exploration by researchers. Secondary analyses can uncover relationships among variables and derive conclusions that may not be captured in initial reports, thereby enriching educational discourse and informing policy discussions.

Various methodologies have been employed to analyze PISA data. Common approaches include multilevel regression analysis (Willms, 2010), structural equation modeling (Acosta & Hsu, 2014; Barnard-Brak, Lan & Yang, 2018), and analysis of covariance (Smith et al., 2018; Zhu & Kaiser, 2020). Recently, data mining techniques have emerged as promising methods for uncovering patterns in large datasets (Gamazo & Martínez-Abad, 2020; She et al., 2019). This study expands on this research tradition by employing multivariate linear regression to examine the impact of ICT on students' mathematics performance in South-East Asian countries.

Existing literature suggests that integrating ICT in schools enhances teaching and learning processes (Sangrà & González-Sanmamed, 2010). For instance, Spiezia (2010) found a positive correlation between frequent computer use and students' science performance in PISA 2006. Similarly, Zhang & Liu (2016) demonstrated that ICT positively impacts learning outcomes when controlling for factors such as national GDP, school type, and ICT investment. Moreover, Srijamdee & Pholphirul (2020) indicated that using ICT for educational purposes can lead to improvements in students' PISA scores in developing countries. In Spain, Fernández-Gutiérrez, Gimenez & Calero (2020) provided evidence that increased ICT usage in schools positively influenced PISA science scores. Among the subjects affected by ICT integration, mathematics education has garnered particular interest due to its critical role in developing logical thinking and problem-solving skills (Smith, 2018). The PISA 2018 survey, in particular, offers a unique opportunity to investigate how ICT use in education correlates with student performance, especially in mathematics. Despite the growing body of research, previous studies have predominantly focused on global or developed regions. For example, Boman & Wiberg (2024) explored the relationship between socio-economic status, migration background, and non-cognitive factors affecting PISA mathematics achievement in Sweden. In another instance, Molina-Muñoz, Contreras-García & Molina-Portillo (2023) analyzed the impact of psycho-emotional characteristics on mathematics literacy in Spain. Skyrabin et al. (2015) examined how national ICT development levels and individual ICT usage influenced mathematics achievements in over 30 countries, finding that national ICT development significantly predicted student performance. While global trends have been extensively studied, there remains a lack of focused research on how ICT affects student performance in specific regions (Chen & Lai, 2015). In particular, there is a scarcity of research exploring the impact of ICT on mathematics performance in the South-East Asian (SEA) region. Characterized by diverse educational systems, socio-economic conditions, and levels of digital infrastructure, South-East Asian countries present a compelling case for examination. Understanding how ICT influences mathematics performance in these countries could offer valuable insights into more effective integration strategies, especially for emerging economies (Ismail & Al-Rahmi, 2020). This study addresses the existing gap by conducting a cross-country analysis to determine the influence of ICT on mathematics performance in South-East Asian countries using PISA 2018 data. By facilitating international comparisons, this study serves as a benchmarking tool, enabling education systems in South-East Asia to evaluate themselves against global counterparts. Such comparisons can foster innovation in how schools and educational systems utilize ICT, providing new insights into the efficient allocation of resources to enhance educational outcomes. This paper is structured as follows. The next section provides a literature review regarding the use of PISA database in the context of South-East Asian countries is provided. Section 3 discusses the methodology, including the empirical model and variables used. Section 4 presents the results and robustness analysis. Finally, Section 5 offers concluding remarks.

2. Literature Review

The literature on the utilization of the Programme for International Student Assessment (PISA) database in the context of South-East Asia is relatively sparse. A search of the Scopus database using the query "PIS" AND ("South-East Asia*" OR ("South East Asia*"))[1] initially yielded eight articles (see Fig. 1). Four of them were removed for further analysis as they did not utilize the PISA database. This section synthesizes the findings from relevant studies, providing insights into the various ways PISA data has been analyzed in this region.

Ulkhaq et al. (2024a) conducted an efficiency evaluation of schools across six South-East Asian countries using a two-stage super-efficiency model. In the first stage, they employed a non-parametric data envelopment analysis (DEA) model

[1]The asterisk sign (*) is used to find a root word plus all the words made by adding letters to the end (or beginning) of it.

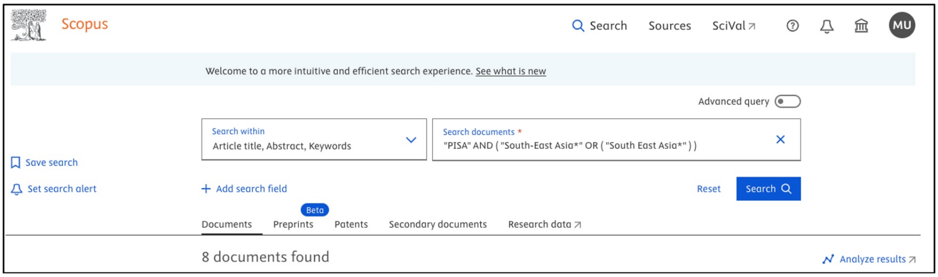


Figure 1: The search result

to rank schools based on performance. Their findings revealed that Singapore had the highest efficiency among the analyzed countries. The second stage of their analysis used bootstrapped quantile regression to explore factors influencing school efficiency. They found that school size, the shortage of educational materials, and the ratio of computers connected to the internet were statistically significant determinants of school efficiency when all PISA domains (reading, mathematics, and science) were considered. Ulkhaq et al. (2024b) assessed school efficiency in six South-East Asian countries using OECD PISA 2018 data. Using stochastic frontier analysis, the study models efficiency across these domains, finding average efficiency scores of 38.47% in math, 48.83% in science, and 49.82% in reading.

Clavel et al. (2022) explored the relationships between academic resilience and non-cognitive skills using PISA 2015 science domain data. Their study compared seven East Asian countries with one South-East Asian country, Singapore. Despite disparities between these countries, their results indicated a positive relationship between students' enjoyment and interest in science and their resilience in the subject. Conversely, instrumental motivation – where students are driven to learn science primarily for career purposes – was negatively related to resilience. Although this study focused on science rather than mathematics, it underscores the role of non-cognitive factors in students' academic performance, which may similarly apply to their performance in mathematics in the South-East Asian context.

Gill & Berezina (2020) examined the relationship between school leadership, decision-making, and staff development practices using the PISA database to compare schools in Indonesia, Malaysia, and Singapore. Their results revealed notable differences in how decision-making and leadership affect school performance. While school principals in Malaysia and Indonesia reported higher levels of autonomy compared to their Singaporean counterparts, Singaporean schools appeared to enjoy greater practical decision-making latitude. This was largely attributed to the delegation of staff development and skills transfer responsibilities to teachers in Singapore, whereas in Indonesia and Malaysia, these functions were controlled by government administrators. The study highlights the critical role of leadership and autonomy in shaping school performance, which may influence how ICT is implemented and utilized in educational settings across these countries.

The existing literature on the utilization of the PISA database in South-East

Asia, though limited, reveals significant insights into school efficiency, the role of non-cognitive skills, and the influence of leadership on school performance. These studies underscore the importance of ICT infrastructure, non-cognitive factors, and decision-making autonomy, which are critical variables when analyzing educational outcomes using PISA data. However, there is a gap in the literature specifically addressing the impact of ICT on mathematics performance in this region, further justifying the focus of the present study on South-East Asia using the PISA 2018 dataset.

3. Methodology

To investigate the influence of ICT on students' mathematics performance, we use a multivariate regression model. The model is denoted as:

$$\begin{aligned} PV\_MATH_i = {} & \alpha + \beta_1 ESCS_i + \beta_2 MMINS_i + \beta_3 SCHSIZE_i + \\ & \beta_4 PROPGIRL_i + \beta_5 STRATIO_i + \beta_6 COMPRATIO_i + \\ & \beta_7 WEBCOMP_i + \varepsilon_i \end{aligned} \tag{1}$$

where PV_MATH represents the PISA score in mathematical literacy (dependent variable), α is the intercept, $\beta_j (j = 1, 2, \ldots 7)$ are the regression coefficients corresponding to each independent variable, ε represents the error term or statistical noise, and i is the subscript indicating the school ($i = 1, 2, \ldots N$). Notice that $ESCS$, $MMINS$, $SCHSIZE$, $PROPGIRL$, $STRATIO$, $COMPRATIO$, and $WEBCOMP$ are the independent variables which will be described as follows.

This study focuses on six South-East Asian (SEA) countries: Brunei Darussalam (BRN), Indonesia (IDN), Malaysia (MYS), the Philippines (PHL), Singapore (SGP), and Thailand (THA). The analysis uses data from the student and school questionnaires in the PISA database. Since the study is conducted at the school level, student-level variables are aggregated using appropriate weights to derive school-level variables.

The dependent variable, students' proficiency in mathematics, is measured by the weighted plausible values (PVs) provided by PISA. These PVs serve as proxies for the PISA mathematics score.

Figure 2 presents the average mathematics performance across schools in each SEA country. The average mathematics score for all schools across the six countries is 424.97 points. Among these countries, Singapore reports the highest average score (561.38), while the Philippines has the lowest (352.73). Indonesia also scores below the regional average, with an average score of 391.65.

The independent variables used in this study include $ESCS$, $MMINS$, $SCHSIZE$, $PROPGIRL$, $STRATIO$, $COMPRATIO$, and $WEBCOMP$. Each of these variables plays a specific role in understanding the factors that may influence students' mathematics performance. A detailed description of these variables is provided in Table 1. These variables were selected from the PISA database based on their relevance to the research objectives and their potential explanatory power regarding the relationship between ICT use and mathematics performance in schools across South-East Asia.

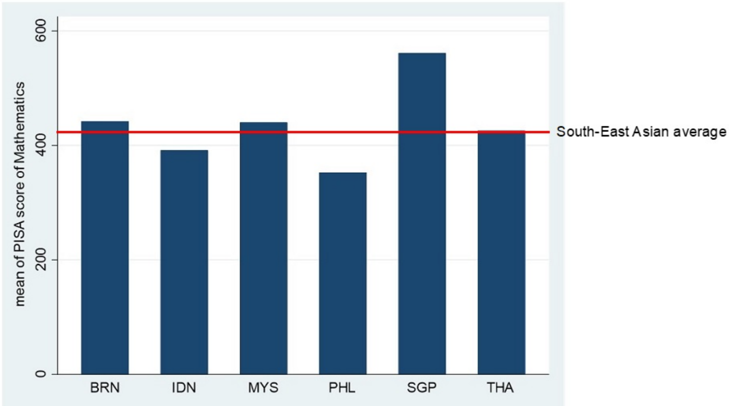


Figure 2: School's average performance in mathematics in South-East Asian countries

Table 1: Description of independent variables

Inputs	**Description**
$ESCS$	Index of economic, social, and cultural status
$MMINS$	Mathematics learning time per week (in minutes)
$SCHSIZE$	School size or number of enrolled students
$PROPGIRL$	Proportion of female students in a school
$STRATIO$	Student-teacher ratio
$COMPRATIO$	Ratio of computers at school to the total number of students for educational purposes
$WEBCOMP$	Ratio of computers at school to the number of these computers that were connected to the internet

The independent variables used in this study will be described as follows. In the PISA framework, $ESCS$ (Economic, Social, and Cultural Status) is a composite measure of students' access to family resources, encompassing financial, social, cultural, and human capital. These factors collectively define the social position of a student's family or household (Avvisati, 2020). Derived from three key indicators – home possessions, parental education, and highest parental occupation – $ESCS$ is a crucial variable in PISA data, often used in reports and secondary analyses, second only to student achievement scores (Avvisati, 2020). Its role in exploring educational opportunities and disparities in learning outcomes stems from the traditional view of socioeconomic status being determined by education, occupation, and income (Sirin 2005; Willms & Tramonte 2019). Numerous studies have demonstrated the variable's explanatory power regarding educational outcomes (e.g., Crespo-Cebada et al., 2014; Salas-Velasco, 2020; Ulkhaq, 2021, 2023a).

Previous research has also explored the influence of other factors such as school size ($SCHSIZE$) and proportion of female students ($PROPGIRL$) on educational outcomes. School size, reflecting the total number of students, has been debated for its impact on academic performance. Some studies suggest that larger schools yield better results (Bradley & Taylor, 1998), while others find no significant effect (Hanushek & Luque, 2003), and still others highlight smaller schools' ability to reduce dropout rates (Mora et al., 2010). Similarly, the gender composition of schools, represented by PROPGIRL, can influence achievement, as evidenced by studies that examine gender dynamics in education (Rodger & Ghosh, 2001; Rudd, 1984).

The student-teacher ratio ($STRATIO$) is another factor that may influence student outcomes. Studies like Ulkhaq et al. (2024a) and Agasisti & Zoido (2019) have shown that lower student-teacher ratios can contribute to improved academic performance by enhancing individualized attention and teaching quality.

Finally, this study considers two ICT-related variables: $COMPRATIO$ (the ratio of computers per student) and $WEBCOMP$ (the availability of computers connected to the internet). $COMPRATIO$ has been employed in research to assess institutional efficiency in various educational contexts, including higher education in Brazil (Zoghbi, Rocha & Mattos, 2013) and school performance in Spain (Perelman & Santín, 2011a). $WEBCOMP$, used in studies such as Perelman & Santín (2011b), evaluates the technological resources available to students, particularly internet access, which plays a crucial role in modern education. Table 2 presents the descriptive statistics of the independent variables, revealing several important insights:

1. The $ESCS$ (Economic, Social, and Cultural Status) has a mean of -1.054 across the six sampled South-East Asian (SEA) countries, indicating that the socio-economic conditions of these students are generally below the OECD average. Among the sampled countries, Singapore reports the highest average $ESCS$, likely reflecting its status as the SEA country with the highest GDP per capita.

2. Gender distribution in schools is relatively balanced, with the average $PROPGIRL$ (proportion of girls) value at 49.84%. However, 17 schools have no female students, including 8 schools in Singapore and 3 schools each in Brunei Darussalam, Malaysia, and Thailand.

3. School sizes vary significantly, ranging from a school in Thailand with only 3 students to a school in the Philippines with 11,990 students – the largest among the sampled schools.

4. In terms of ICT-related variables, 20 sampled schools do not have computers. These schools are distributed across Malaysia (7 schools), the Philippines and Indonesia (6 schools each), and Singapore (1 school). Additionally, 64 schools have computers but lack internet access.

Table 2: Descriptive statistics by country

Variables	Total	BRN	IDN	MYS	PHL	SGP	THA
Number of students	47,579	6,828	12,098	6,111	7,233	6,676	8,633
Number of schools	1,286	55	397	191	187	166	290
Mean of ESCS	-1.054	-0.164	-1.472	-0.763	-1.423	0.133	-1.283
Mean of MMINS	265.588	227.153	255.908	241.651	316.567	310.268	243.548
Mean of SCHSIZE	1,218.428	867.273	571.055	1,097.058	2,300.610	1,165.133	1,392.249
Mean of PROPGIRL	0.498	0.482	0.497	0.493	0.508	0.495	0.502
Mean of STRATIO	16.444	9.305	16.936	11.620	25.600	11.257	17.504
Mean of COMPRATIO	0.522	0.898	0.362	0.372	0.303	1.083	0.533
Mean of WEBCOMP	0.835	0.970	0.806	0.859	0.526	0.991	0.935

4. Results and Discussion

The regression analysis, detailed in Table 3, was performed using the ordinary least squares (OLS) method. The sign of each regression coefficient offers key insights: a positive coefficient suggests that an increase in the corresponding independent variable leads to an expected increase in the dependent variable, while a negative coefficient indicates a decrease. Additionally, the magnitude of the coefficient reflects the extent to which the dependent variable is expected to change with a one-unit increase in the independent variable, assuming all other factors remain constant. This allows us to isolate and assess the unique contribution of each variable to the model. Furthermore, the statistical significance of each coefficient is important for interpreting the results. Among all the independent variables included in the analysis, only $SCHSIZE$ (school size) exhibits statistically insignificant coefficients, indicating that it does not have a meaningful impact on the dependent variable in this context.

Table 3: Results of parameter estimation

Variable	Coef.	Std. Error	p-value	VIF	PV2
Constant	442.675**	9.687	0		442.464**
ESCS	65.412**	1.791	0	1.37	65.001**
MMINS	0.067**	0.020	0	1.06	0.067**
SCHSIZE	-0.00025	0.001	0.833	1.32	-0.0002
PROPGIRL	30.241**	9.965	0.002	1.02	26.429**
STRATIO	-1.061**	0.206	0	1.46	-1.0449**
COMPRATIO	13.712**	2.501	0	1.17	14.219**
WEBCOMP	35.671**	4.764	0	1.14	37.6145**

**significant at the level of 5%

The positive coefficient of $ESCS$ indicates that higher aggregated economic, social, and cultural status at the school level correlates with better PISA scores, consistent with findings from prior studies, such as Ferrera et al. (2011), Salas-Velasco (2020), and Ulkhaq (2022a, 2022b, 2023a, 2023b). Similarly, the positive coefficient for the proportion of female students (PROPGIRL) suggests that as the proportion of female students in a school increases, the PISA mathematics score also tends to rise. This finding diverges from Mancebón et al. (2012), who reported that while girls generally outperform boys in language, boys tend to excel in mathematics and science based on PISA 2006 results.

The negative coefficient for the student-teacher ratio ($STRATIO$) indicates that an increase in this ratio leads to a decline in school performance, in line with expectations. This is consistent with previous studies by Franta & Konecny (2009) and Mizala et al. (2002), which also found a negative relationship between student-teacher ratios and educational outcomes. It supports the conventional view that smaller class sizes foster better learning environments (Chakraborty et al., 2001). However, the insignificance of the school size variable ($SCHSIZE$) suggests a potentially nonlinear relationship, as highlighted by Bradley & Taylor (1998). There may be a threshold beyond which schools become "too large," resulting in management and disciplinary challenges (Haller 1992).

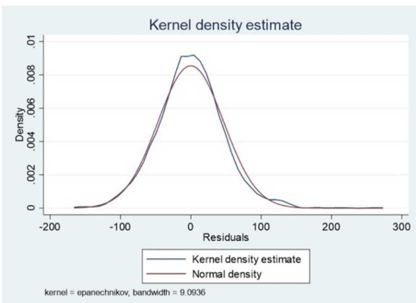
Regarding ICT variables, both $COMPRATIO$ (computer availability) and $WEBCOMP$ (internet connectivity) are statistically significant at the 5% level. This suggests that increasing access to computers and ensuring internet connectivity at schools can lead to improved PISA scores, in agreement with the findings of García-Díaz et al. (2016), who observed a positive and significant impact of internet access on educational outcomes. Next, we examine the classical assumptions underlying our regression analysis.

1. Normality of residuals: The first assumption tested is whether the residuals follow a normal distribution. A kernel density plot (Fig. 3(a)) shows that the residuals closely resemble a normal distribution, supporting the hypothesis that the residuals are normally distributed.

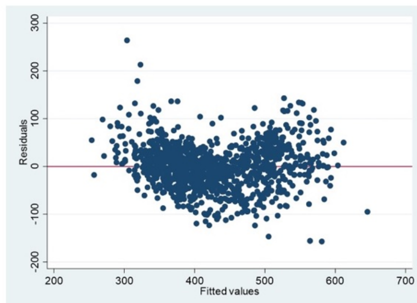
2. Homoscedasticity: The second assumption is homoscedasticity, meaning the variance of the residuals should be constant across all levels of the fitted values. In Figure 3(b), the residuals are plotted against the fitted values, and no discernible pattern is observed, indicating that the assumption of homoscedasticity holds.

3. Multicollinearity: This occurs when two or more independent variables are highly correlated, potentially distorting the regression results. To assess this, we use the variance inflation factor (VIF). A VIF value greater than 10 suggests multicollinearity, but as shown in Table 3 (VIF column), all independent variables have VIF values below 10, indicating no multicollinearity issues.

To test the robustness of our findings, we examine whether the sign and significance of the variables change when using alternative plausible values (PVs) as the dependent variables. In academic performance research, student proficiencies are often unobservable and must be inferred from observed responses, such as those in the PISA assessment. PISA employs an imputation method called plausible values (PVs), which represent probable proficiencies for students based on their scores. Table 3 (column: PV2) presents the results of this robustness analysis, where PV2 is used as the dependent variable. Notably, the sign and significance of all coefficients remain consistent. For instance, the coefficients of $ESCS$, $MMINS$, and $PROPGIRL$ continue to be positively significant, while the coefficient of $STRATIO$ remains negatively significant. Similarly, $SCHSIZE$ remains non-significant. The ICT-related variables, $COMPRATIO$ and $WEBCOMP$, also retain their positive and significant values. Upon closer inspection, the coefficients' values show only minor differences, suggesting that the variations are trivial. In summary, the findings indicate that the model is robust, as the changes in dependent variables do not meaningfully affect the sign or significance of the coefficients.



(a) Normality of residuals



(b) Homogeneity of variance of residuals

Figure 3: Testing the classical assumptions

Based on the findings regarding the influence of ICT on students' mathematics performance in South-East Asian countries, several practical and policy implications emerge. First and foremost, schools should prioritize investing in ICT infrastructure, ensuring that all institutions, particularly those in underserved areas, have access to reliable internet and sufficient computers for students. Additionally, targeted training for educators is essential to equip them with the skills necessary to effectively integrate ICT tools into their teaching practices, thereby enhancing learning outcomes in mathematics. The findings also suggest the importance of promoting gender balance in classrooms; initiatives aimed at encouraging female participation in STEM (Science, Technology, Engineering, and Mathematics) subjects can contribute to improved overall student performance.

Furthermore, while school size did not show a significant impact, the negative correlation with the student-teacher ratio indicates the need for policies that promote smaller class sizes, as reducing the number of students per teacher can lead to more personalized instruction and improved engagement. Addressing socioeconomic disparities is also crucial, as students' socioeconomic status ($ESCS$) significantly influences academic performance. Educational policies should, therefore, focus on providing additional support and resources to schools serving lower-income populations, such as tutoring and access to learning materials, to help bridge the achievement gap.

From a policy perspective, governments in the region should develop strategic ICT policies aimed at enhancing digital literacy among both students and teachers, incorporating technology into national educational standards and curricula. Establishing monitoring and evaluation mechanisms is essential to assess the impact of ICT initiatives on educational outcomes, enabling policymakers to identify effective practices and areas for improvement. Additionally, cross-national collaborations among South-East Asian countries can foster the sharing of best practices and resources related to ICT in education, enhancing the effectiveness of integration across diverse educational systems. Engaging parents and communities in supporting these initiatives can further amplify their impact, as programs that educate families on the importance of technology in education can enhance student motivation and success.

5. Conclusion and Future Research Directions

This research investigated the influence of Information and Communication Technology (ICT) on students' mathematics performance in South-East Asian countries. By analyzing the latest 2018 PISA data through multivariate linear regression, the study revealed that all ICT-related variables significantly affected mathematics performance. Specifically, increasing computer availability and internet connectivity in schools can enhance PISA mathematics scores. Furthermore, given that the Economic, Social, and Cultural Status ($ESCS$) encompasses components related to ICT – such as home possession of ICT resources – and that $ESCS$ was found to significantly influence PISA mathematics scores, the findings suggest that improving ICT-related home possessions could also positively impact student performance.

Overall, this study highlights the critical role of ICT in enhancing mathematics achievement in South-East Asia. Among the seven independent variables analyzed, six were found to be statistically significant in influencing students' mathematics performance. The positive coefficient of $ESCS$ indicates that higher economic, social, and cultural status correlates with higher PISA mathematics scores. Similarly, the positive coefficient for the proportion of female students suggests that as the percentage of female students in a school increases, the PISA mathematics scores tend to improve. Conversely, the negative coefficient for the student-teacher ratio implies that an increase in this ratio is associated with a decrease in students' mathematics performance. Regarding ICT, both $COMPRATIO$ and $WEBCOMP$ were statistically significant at the 5% level, indicating that increasing the number of available computers and ensuring internet connectivity can lead to improved PISA mathematics scores.

In conclusion, the findings emphasize the importance of integrating ICT into educational policies and practices to foster better mathematics outcomes for students in South-East Asian countries. Implementing these practical and policy implications can help enhance students' mathematics performance in South-East Asia by leveraging ICT effectively. A coordinated approach involving investment, training, support for diverse learners, and evidence-based policy development is essential for driving positive educational outcomes in the region.

Future research directions in the field of ICT's impact on mathematics performance in South-East Asia could include several key areas. First, conducting longitudinal studies would be beneficial to examine the long-term effects of ICT integration on students' mathematics outcomes, providing insights into the sustainability of such interventions (Fuchs & Woessmann, 2004). Second, employing qualitative research methods, such as interviews and focus groups with educators, students, and parents, could reveal contextual factors influencing ICT integration that quantitative studies may overlook (Creswell & Poth, 2018). Third, comparative studies that investigate the impact of ICT on mathematics performance in South-East Asian countries relative to other regions, such as East Asia or Western countries, could highlight unique regional challenges and effective strategies for ICT implementation (Li & Ma, 2010). Finally, exploring the role of teacher training and professional development in effectively integrating ICT into mathematics education could provide valuable insights into how teachers' proficiency with technology influences student outcomes (Ertmer & Ottenbreit-Leftwich, 2010). These research avenues could significantly enhance our understanding of the effective use of ICT in education.

Conflicts of Interest

No conflicts of interest to declare.

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