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Digital Divide and Educational Inequality in Asia: A Cross-Country Secondary Data Analysis of Connectivity, Access, and Student Achievement

Mhel Cedric D. Bendo [1]* **and Domar C. Alviar** [2]

[1] College of Business Administration, Polytechnic University of the Philippines–Maragondon Campus, Philippines
[2] Arts and Languages Department, College of Education, Arts, and Sciences, National University–Manila, Philippines

ABSTRACT

The increasing reliance on digital technologies in education has intensified concerns regarding unequal access to digital resources across countries, particularly in developing regions. While digital connectivity has the potential to enhance learning opportunities, disparities in internet access and technological infrastructure may contribute to unequal educational outcomes. This study examines the relationship between the digital divide and educational inequality in Asia through a cross-country secondary data analysis of connectivity, access, and student achievement. Using publicly available datasets from the World Bank, the Organisation for Economic Co-operation and Development (OECD), and the International Telecommunication Union (ITU), the study analyzes key indicators of internet access, digital infrastructure, student achievement, and educational inequality across selected Asian countries. Descriptive statistics, correlation analysis, and multiple regression models were employed to examine structural associations among variables. The results indicate that internet access is positively associated with student achievement and negatively associated with educational inequality. Digital infrastructure also demonstrates positive associations with educational performance and lower levels of inequality. In contrast, rural population is negatively associated with student achievement and positively associated with educational inequality. Overall, the findings highlight the importance of digital connectivity and technological capacity in shaping both the quality and equity dimensions of education systems across diverse national contexts.

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CONTACT Mhel Cedric D. Bendo cedricbends@gmail.com College of Business Administration, Polytechnic University of the Philippines, Cavite, Philippines **ISSN : 3030-6582 (Printed), eISSN : 3030-5330 (Online).** DOI 10.70148/rise.v3i4.9.

1. Introduction

The rapid expansion of digital technologies has fundamentally transformed educational systems worldwide, reshaping how students access information, engage with learning materials, and participate in academic environments. Digital connectivity, particularly internet access, has become a critical component of modern education, enabling access to online resources, digital platforms, and technology-enhanced learning opportunities (OECD, 2023; Selwyn, 2016). However, despite these advancements, substantial disparities in digital access persist across countries, particularly within developing regions, raising concerns about the emergence of a global digital divide in education (International Telecommunication Union [ITU], 2023; Hilbert, 2016).

In many educational contexts, unequal access to digital infrastructure has created significant differences in students' ability to participate in technology-mediated learning. Students in highly connected environments benefit from greater access to digital tools, online educational content, and interactive platforms, whereas those in less connected or rural areas face structural limitations that hinder their academic development (World Bank, 2024; Warschauer, 2004). These disparities extend beyond technological access and translate into broader educational inequalities, influencing student performance, learning outcomes, and overall academic achievement (OECD, 2023). As digital learning becomes increasingly embedded in formal education systems, connectivity has emerged as a key determinant of educational opportunity and success.

Existing literature has widely recognized the role of digital technologies in enhancing learning outcomes and expanding educational opportunities. Empirical studies indicate that access to digital resources supports student engagement, facilitates knowledge acquisition, and promotes more flexible and personalized learning environments (Tamim et al., 2015; Bulman & Fairlie, 2016). At the same time, research highlights that unequal access to these resources may exacerbate existing educational disparities, particularly between urban and rural populations and between developed and developing countries (Van Dijk, 2020; Robinson et al., 2015). These findings suggest that the digital divide is not merely a technological issue but a critical factor shaping educational equity and inclusion.

Despite increasing scholarly attention to digital inequality, much of the existing research remains conceptual or limited to single-country analyses, with relatively few studies providing cross-country empirical evidence on the relationship between digital access and educational outcomes. In particular, there is a lack of quantitative studies that simultaneously examine connectivity, student achievement, and educational inequality using comparable international datasets such as PISA and global ICT indicators (OECD, 2023; ITU, 2023). This limitation constrains a comprehensive understanding of how digital disparities influence education at a broader, systemic level.

Addressing this gap, the present study conducts a cross-country secondary data analysis of selected Asian countries to examine the relationship between internet access, student achievement, and educational inequality. By integrating data from international sources and applying quantitative analytical techniques, the study aims to provide empirical evidence on how digital connectivity shapes both the quality and equity of education systems. This research contributes to the growing body of literature on digital inequality by offering a comparative perspective that highlights the role of digital access in influencing educational outcomes across diverse national contexts.

Asia was selected as the focus of the study because the region demonstrates substantial variation in digital development, educational performance, technological infrastructure, and socio-economic conditions across countries. This diversity provides an appropriate comparative context for examining how differences in digital connectivity relate to educational achievement and inequality across contrasting national educational systems.

2. Literature Review

2.1. Digital Divide and Dimensions of Digital Inequality

The concept of the digital divide has evolved from a narrow focus on physical access to technology into a broader multidimensional framework encompassing disparities in access, digital skills, usage, and outcomes (Van Dijk, 2020). Contemporary scholarship emphasizes that digital inequality extends beyond infrastructure availability and includes differences in individuals' capacity to effectively utilize digital technologies for meaningful participation in educational, social, and economic activities.

In many developing contexts, disparities in digital access remain highly uneven, particularly between urban and rural communities. Limited infrastructure, unstable internet connectivity, and unequal distribution of educational resources continue to restrict participation in technology-mediated learning environments (UNESCO, 2023; World Bank, 2024). These structural inequalities often reinforce broader socio-economic disadvantages, limiting opportunities for marginalized populations to benefit from digital transformation.

Recent literature further suggests that digital inequality should be understood as a structural and systemic issue rather than a purely technological concern. Differences in access, technological readiness, institutional support, and digital competence collectively shape educational participation and learning opportunities across national contexts.

2.2. Digital Connectivity and Its Influence on Student Achievement

A growing body of research highlights the relationship between digital connectivity and student learning outcomes. Access to online educational resources, digital learning platforms, and technology-mediated instruction has been associated with improved student engagement, participation, and academic performance (Tamim et al., 2015). However, the educational benefits of digital technologies depend not only on availability of access but also on the quality of integration within educational systems.

Empirical studies indicate that students with stable internet connectivity are generally better positioned to participate in online and blended learning environments, particularly in contexts where digital technologies are embedded in formal educational practices (Barrot et al., 2021). Conversely, limited connectivity constrains access to learning materials, communication platforms, and interactive instructional environments, potentially reducing academic performance and learning continuity.

Recent evidence further suggests that digital learning environments influence not only access to information but also broader cognitive and instructional processes, including engagement, concentration, and participation in self-directed learning activities (Bendo, 2026). These findings indicate that digital connectivity increasingly functions as a foundational condition for participation in contemporary educational systems.

2.3. Digital Infrastructure and the Development of Educational Systems

Beyond household connectivity, digital infrastructure represents a broader structural dimension of educational development. Investments in ICT systems, broadband networks, and national technological readiness enhance the capacity of educational institutions to implement digital learning environments and support instructional innovation (OECD, 2023). In this context, digital infrastructure functions as a system-level condition enabling educational technologies to be effectively integrated into teaching and learning processes.

Existing studies consistently demonstrate that infrastructure alone is insufficient without complementary institutional support, teacher preparedness, and pedagogical integration (Alviar, 2023). The effectiveness of digital technologies therefore depends not only on technological availability but also on the institutional capacity of educational systems to utilize these resources meaningfully.

Research across Asian contexts further suggests that countries with stronger ICT infrastructure and technological readiness generally demonstrate more advanced digital learning environments and stronger educational outcomes (Lee & Lee, 2024; Lim et al., 2019). At the same time, unequal infrastructure distribution continues to reinforce disparities in educational quality and access across regions and socio-economic groups.

2.4 Educational Inequality in Relation to Digital Access

Educational inequality is closely associated with disparities in access to digital resources, learning environments, and technological opportunities. Unequal distribution of internet connectivity, digital devices, and educational technologies contributes to differences in participation and academic performance across socio-economic groups (OECD, 2023). In digitally mediated learning environments, disadvantaged students often experience reduced access to educational resources necessary for effective participation.

Research suggests that digital access may both alleviate and reinforce educational inequality depending on how connectivity and technological resources are distributed within educational systems (Billion et al., 2021). While expanded access has the potential to increase educational participation and learning opportunities, unequal distribution of digital resources may simultaneously widen achievement gaps between advantaged and disadvantaged groups.

These findings indicate that digital technologies do not automatically produce equitable educational outcomes. Instead, the educational impact of digital access depends on broader structural, institutional, and socio-economic conditions shaping technology utilization and participation.

2.5. Rural Disparities as a Structural Determinant of Educational Inequality

Rural populations continue to experience distinct barriers in accessing both digital and educational resources. Geographic isolation, weaker technological infrastructure, and lower institutional investment contribute to persistent disparities in connectivity and learning opportunities across rural communities (Jafar et al., 2023). These structural limitations reduce the ability of digital technologies to effectively support educational participation in underserved areas.

Empirical evidence further indicates that rural students are more likely to experience lower levels of connectivity, weaker educational support systems, and lower academic performance compared with students in urban environments (Guo & Wan, 2022). These disparities reflect broader structural inequalities extending beyond technology itself, including socio-economic conditions, institutional capacity, and uneven educational development.

Within comparative educational contexts, rural population therefore functions as an important structural factor influencing both digital participation and educational inequality across countries.

2.6. Digital Skills, Usage, and Their Role in Shaping Inequality

Recent literature emphasizes that digital inclusion depends not only on access and infrastructure but also on individuals' ability to effectively utilize digital technologies. Even in contexts where technological resources are available, disparities in digital competence may limit meaningful participation in educational activities (Nguyen et al., 2024). This highlights the importance of digital skills as a critical dimension of educational participation within increasingly technology-mediated learning environments.

Studies also demonstrate that socio-economic background, educational attainment, and regional development influence patterns of digital usage and participation (Puspitasari & Ishii, 2016). As a result, differences in digital competence may continue to reproduce educational inequalities even when access gaps are reduced.

Collectively, the literature suggests that digital inequality operates through interconnected dimensions of access, infrastructure, skills, and structural socio-economic conditions. These factors jointly influence both the quality and

equity of educational outcomes across countries, reinforcing the need for integrated comparative analysis within rapidly evolving digital learning environments.

2.7. Research Gap and Contribution of the Present Study

Despite extensive scholarship on digital inequality and educational technology, several important gaps remain in the literature. Many existing studies focus primarily on single-country contexts or specific institutional settings, limiting broader comparative understanding across national educational systems. In addition, relatively few empirical studies simultaneously examine digital connectivity, educational inequality, and student achievement using internationally comparable datasets.

Within the Asian context, countries demonstrate substantial variation in technological development, educational performance, and digital infrastructure. However, existing research often examines these dimensions independently rather than as interconnected structural components influencing educational quality and equity.

Addressing these limitations, the present study employs cross-country secondary data analysis to examine how internet access, digital infrastructure, and rural population are associated with student achievement and educational inequality across selected Asian countries. By integrating internationally comparable datasets from the World Bank, OECD PISA, and ITU, the study contributes to a more comprehensive understanding of how digital connectivity shapes both the performance and equity dimensions of education systems within diverse national contexts.

2.8. Theoretical Framework

This study is anchored primarily in Digital Divide Theory, supported by Human Capital Theory and the Educational Production Function framework, to explain the relationship between digital connectivity, student achievement, and educational inequality across countries.

Digital Divide Theory provides the central foundation of the study by explaining how inequalities in access to information and communication technologies (ICT) contribute to disparities in educational opportunities and outcomes (Van Dijk, 2020). The theory emphasizes that digital inequality extends beyond physical access and includes differences in technological usage and outcomes. In educational contexts, unequal digital access may limit students' participation in learning activities, access to information, and academic development. Accordingly, countries with stronger internet access and digital infrastructure are expected to demonstrate higher educational performance and lower levels of inequality.

The study is further supported by Human Capital Theory, which suggests that investments in educational resources enhance knowledge, skills, and productivity (Becker, 1993). Digital technologies function as educational resources that support learning, information access, and academic engagement. From this perspective, improved digital connectivity expands learning opportunities, while limited access constrains educational participation and achievement.

In addition, the Educational Production Function framework conceptualizes educational outcomes as products of various structural and institutional inputs, including infrastructure, technological resources, and socio-economic conditions. Within this framework, digital connectivity and ICT infrastructure are treated as educational inputs influencing both student achievement and educational inequality. Rural population is also incorporated as a structural factor that may constrain access to educational and technological resources across countries.

Collectively, these theoretical perspectives provide an integrated explanation of how digital connectivity influences both the quality and equity dimensions of education systems. Digital Divide Theory explains disparities in access and outcomes, Human Capital Theory explains how digital resources support learning, and the Educational Production Function framework links technological and structural inputs to educational performance across national contexts.

3. Conceptual Framework

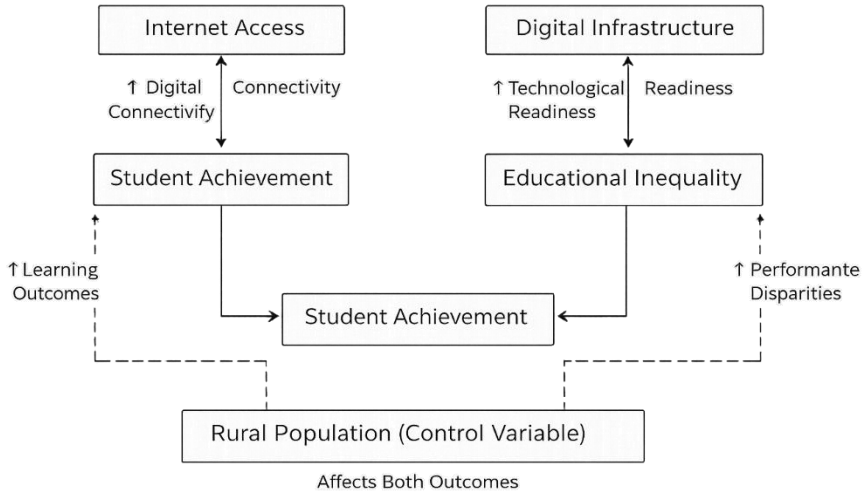

***Figure 1**. Conceptual Framework Linking Digital Connectivity and Educational Outcomes*

Figure 1. presents the conceptual framework guiding the study. The framework illustrates the structural relationship between digital connectivity and educational outcomes across national contexts. Internet access and digital infrastructure are conceptualized as related but analytically distinct dimensions of digital development influencing both student achievement and educational inequality.

Within the framework, internet access refers to household and learner connectivity, while digital infrastructure reflects broader institutional and technological capacity supporting digital learning environments. These dimensions are expected to influence educational outcomes by shaping access to educational resources and participation in technology-mediated learning.

Rural population is incorporated as a contextual structural variable representing geographic and socio-economic disparities that may constrain access to technological and educational opportunities. The framework assumes that variations in connectivity, infrastructure, and structural conditions contribute to differences in both educational performance and equity across countries.

The conceptual model is grounded in Digital Divide Theory, Human Capital Theory, and the Educational Production Function framework, which collectively explain how technological access, institutional capacity, and structural conditions shape educational quality and inequality across educational systems.

3.1 Hypotheses Development

Grounded in the theoretical and conceptual framework of the study, the following hypotheses are proposed to examine the structural relationships between digital connectivity, student achievement, and educational inequality across selected Asian countries:
H1: Internet access is positively associated with student achievement.
H2: Digital infrastructure is positively associated with student achievement.
H3: Internet access is negatively associated with educational inequality.
H4: Digital infrastructure is negatively associated with educational inequality.
H5: Rural population is negatively associated with student achievement and positively associated with educational inequality.

4. Methods

4.1. Research Design

This study employed a quantitative cross-country secondary data analysis research design to examine the relationship between digital connectivity, student achievement, and educational inequality across selected Asian countries. Secondary data analysis refers to the systematic use of existing datasets generated by international institutions to produce new empirical insights without direct data collection (Heaton, 2008; Johnston, 2017).

This research design is particularly appropriate for the present study because it enables the integration of large-scale, internationally comparable datasets across multiple countries. In contrast to micro-level or survey-based approaches, the study focuses on macro-level indicators that reflect national patterns of digital access, technological infrastructure, and educational performance. This allows for a broader examination of structural inequalities in education systems across different socio-economic contexts.

Furthermore, the cross-country design supports comparative analysis by identifying variations in digital connectivity and their corresponding relationships with student achievement and educational inequality. Consistent with contemporary quantitative research in global education, the study adopts an explanatory and comparative approach, aiming to identify statistical patterns rather than establish causal relationships. Given the non-experimental nature of the design, findings are interpreted as associations between variables within and across national contexts.

4.2. Data Sources

The study utilized publicly available secondary datasets obtained from internationally recognized institutions to ensure data reliability, comparability, and validity. Data on internet access and rural population were obtained from the World Bank World Development Indicators, which provide standardized global statistics on digital connectivity and demographic distribution. Student achievement and educational inequality indicators were derived from recent OECD Programme for International Student Assessment (PISA) datasets, which provide internationally comparable measures of student performance in mathematics, reading, and science.

Additional indicators related to digital infrastructure were obtained from the International Telecommunication Union (ITU), which provides global data on ICT development and digital connectivity. These datasets were selected because they offer consistent and comparable indicators across countries, enabling cross-country analysis of digital access and educational outcomes.

4.3. Sample and Analytical Scope

The study focused on selected Asian countries representing different levels of digital development, economic structure, and educational performance. The countries included in the analysis were Indonesia, Philippines, Malaysia, Thailand, Vietnam, Singapore, Japan, South Korea, and China. These countries were purposively selected to capture substantial variation in digital connectivity, technological infrastructure, rural population distribution, and educational outcomes across both developed and emerging Asian economies.

The selected countries represent diverse national educational systems and digital ecosystem conditions within the Asian region. Developed economies such as Singapore, Japan, and South Korea demonstrate high levels of digital infrastructure and educational performance. Developing contexts such as the Philippines and Indonesia demonstrate varying levels of digital access and structural educational inequality. This variation supports comparative macro-level analysis of digital connectivity and educational outcomes across contrasting socio-economic contexts.

The unit of analysis in the study is the country rather than individual learners or institutions. Consequently, the study adopts a macro-comparative and exploratory analytical perspective consistent with cross-country secondary data research utilizing internationally harmonized datasets. Although the number of countries included in the analysis is relatively limited, macro-level comparative educational studies frequently employ smaller country samples due to

constraints in internationally comparable data availability, indicator consistency, and harmonized measurement across countries.

Given the limited sample size, the findings are interpreted cautiously as indicative of structural associations and cross-country patterns rather than definitive causal relationships. The study therefore emphasizes exploratory comparative interpretation rather than broad statistical generalization to all Asian educational systems.

Although OECD PISA participation and reporting cycles vary across countries, the study utilized the most recent publicly available internationally comparable achievement indicators for each national context. The analysis therefore emphasizes broad comparative educational patterns across countries rather than strict single-cycle equivalence of assessment administration. Consequently, the findings should be interpreted as exploratory macro-level associations rather than precise cross-cycle performance comparisons.

4.4. Variables and Measurement

The study operationalized several key variables derived from international datasets. Internet access was measured as the percentage of households with internet connectivity, representing the level of digital access within each country. Student achievement was measured using average PISA scores across mathematics, reading, and science, reflecting overall academic performance. Educational inequality was operationalized as the performance gap between high- and low-performing student groups, based on PISA indicators.

Rural population was included as a contextual variable representing structural disparities in access to educational and technological resources. Digital infrastructure was measured using ICT development indicators reflecting national technological readiness. These variables collectively capture the key dimensions of digital access, educational performance, and inequality relevant to the study.

Although internet access and digital infrastructure are conceptually related, the study treats them as analytically distinct dimensions of digital connectivity. Internet access refers specifically to the extent to which households and learners are able to connect to the internet within a national context, primarily reflecting user-level availability and accessibility of digital connectivity. In contrast, digital infrastructure represents broader system-level technological capacity, including ICT development, broadband systems, network readiness, and national technological support structures that enable digital learning environments and technology-mediated education.

Accordingly, internet access captures the availability of connectivity at the user or household level, whereas digital infrastructure reflects the broader institutional and technological ecosystem supporting digital participation across educational systems. This distinction is consistent with contemporary digital divide literature, which differentiates between access-based indicators and broader structural dimensions of technological development (Van Dijk, 2020; Hilbert, 2016).

4.4.1 Variable Construction and Dataset Harmonization

To ensure comparability across countries, all variables were derived from internationally standardized datasets obtained from the World Bank, OECD PISA datasets, and the International Telecommunication Union (ITU). Dataset integration involved harmonizing indicators using country-level national statistics corresponding to the most recent comparable reporting periods available across sources.

Internet access was operationalized as the percentage of households with internet connectivity based on World Bank and ITU indicators. This variable reflects the overall level of digital access available to learners and households within each national context.

Student achievement was measured using average national PISA achievement scores in mathematics, reading, and science. Composite mean scores were utilized to provide a broader representation of overall academic performance across countries rather than relying on a single subject domain.

Educational inequality was operationalized using national-level PISA achievement gap indicators reflecting disparities in student performance between higher- and lower-performing socio-economic groups. Specifically, the study utilized score differences between top and bottom performance quartiles reported within OECD PISA datasets. Higher values indicate wider disparities in educational outcomes and greater levels of inequality across student groups.

Digital infrastructure was measured using ICT development indicators obtained from the ITU and supplementary World Bank digital development statistics. The variable incorporated indicators related to broadband connectivity, ICT access, and national technological readiness to reflect broader structural digital capacity beyond household internet access alone.

To improve cross-country comparability, all indicators were examined for consistency in scale, reporting year, and measurement definitions prior to analysis. Only harmonized national-level indicators with publicly available and internationally standardized measurement procedures were included in the final dataset.

4.5. Data Analysis Procedures and Analytical Techniques

The data were analyzed using quantitative statistical techniques to examine relationships among variables across countries. The analysis was conducted in three stages.

First, descriptive statistics were employed to summarize the levels and distribution of internet access, digital infrastructure, student achievement, and educational inequality, including mean values, standard deviations, and range indicators. This step provided an overview of digital access and educational outcomes across the selected sample.

Second, correlation analysis was conducted to assess the strength and direction of relationships between digital connectivity, student achievement, and educational inequality. Correlation analysis provides preliminary evidence of associations among variables and identifies potential patterns in cross-country data (Field, 2013).

Third, multiple regression analysis was performed to examine the structural associations between internet access, digital infrastructure, rural population, student achievement, and educational inequality across countries. Regression models enable the estimation of relationships between independent and dependent variables while accounting for contextual factors such as rural population.

Given the relatively small country-level sample, the regression models utilized a limited set of explanatory variables to preserve analytical stability and reduce risks of overfitting. Although additional contextual variables such as GDP per capita, education expenditure, governance quality, teacher effectiveness, and broader socio-economic inequality may also influence educational outcomes, including a large number of predictors within a limited cross-country sample may weaken model stability and increase multicollinearity concerns. Consequently, the study adopted a parsimonious exploratory modeling approach focused primarily on structural dimensions of digital connectivity and educational access.

These analytical procedures enabled the identification of comparative patterns and statistical associations between digital access and educational outcomes across national contexts, providing empirical evidence aligned with the objectives of the study. Given the cross-sectional and secondary nature of the data, the findings are interpreted as indicative of structural associations rather than definitive causal relationships.

4.6. Assumption Testing and Regression Diagnostics

Prior to conducting regression analysis, diagnostic procedures were performed to examine whether the data reasonably satisfied the assumptions of linear regression. Given the macro-level and exploratory nature of the study, the diagnostic procedures were interpreted cautiously and used primarily to assess the overall robustness and stability of the regression models.

Normality of residuals was assessed through residual histograms, normal probability plots (P-P plots), and Shapiro-Wilk tests. The results indicated no severe violations of residual normality. Homoscedasticity was examined through scatterplot inspection of standardized residuals against predicted values, which suggested no major heteroscedasticity concerns.

Multicollinearity diagnostics were also conducted to assess conceptual overlap among the predictor variables. Variance Inflation Factor (VIF) and tolerance statistics were examined for all independent variables. All VIF values remained below the commonly accepted threshold of 5.0, while tolerance values exceeded the minimum acceptable level of 0.20, indicating the absence of severe multicollinearity.

Because the study utilized a relatively small cross-country sample, the regression findings were interpreted as exploratory and associational rather than causal. The analysis therefore emphasizes comparative structural relationships among variables rather than predictive generalization.

4.7. Ethical Considerations

This study followed ethical standards applicable to secondary data research. All data were obtained from publicly accessible and reputable institutional sources, and no direct involvement of human participants was required. Since the datasets are aggregated at the country level and do not contain personally identifiable information, the study poses minimal ethical risk. Proper acknowledgment of data sources was maintained to ensure transparency and responsible data use (Heaton, 2008). Given the nature of the data, formal ethical approval was not required.

5. Results

The results section presents the statistical analyses examining the relationships among digital connectivity, digital infrastructure, rural population, student achievement, and educational inequality across selected Asian countries. The analyses were organized sequentially to present variable operationalization, descriptive statistics, correlation patterns, regression models, and diagnostic procedures assessing model robustness. Collectively, these analyses were conducted to examine how structural dimensions of digital access are associated with educational performance and inequality across diverse national contexts.

Table 1. Operational Definition and Measurement of Variables

Variable	Definition	Measurement Indicator	Data Source
Internet Access	Extent of digital connectivity among households and learners	Percentage of households with internet access	World Bank / ITU
Educational Inequality	Disparities in student performance across socio-economic or geographic groups	Difference in PISA scores (top vs bottom quartile / urban vs rural)	OECD PISA
Student Achievement	Overall level of academic performance among students	Average PISA score (Mathematics, Reading, Science)	OECD PISA
Rural Population	Proportion of the population residing in rural areas	Percentage of rural population	World Bank
Digital Infrastructure	Level of national development in information and communication technology (ICT)	ICT index / broadband subscriptions	ITU / World Bank

Source: Adapted from World Bank (2024); OECD PISA Database (2022); International Telecommunication Union (2023).

This table presents the operational definitions and measurement indicators of key variables used in the study. The variables capture digital access, educational inequality, and student performance using internationally comparable datasets.

Table 2. Sample Countries and Key Indicators

Country	Internet Access (%)	Student Achievement (PISA)	Educational Inequality (Gap)	Rural Population (%)
Indonesia	65.5	379	110	43.4
Philippines	59.0	353	120	52.6
Malaysia	89.6	438	85	22.5
Thailand	77.8	419	92	48.7
Vietnam	75.2	496	70	62.7
Singapore	92.0	543	60	0.0
Japan	93.3	536	65	8.2
South Korea	96.8	527	68	18.4
China	70.4	514	75	35.0

Source: Compiled from World Bank (2024), OECD (2023), and ITU (2023).

This table presents the selected countries included in the analysis along with key indicators of digital access, student achievement, educational inequality, and rural population. The sample includes a mix of developed and emerging economies to capture variation in digital infrastructure and educational outcomes across different national contexts.

Table 3. Descriptive Statistics of Key Variables

Variable	Mean	SD	Minimum	Maximum
Internet Access (%)	76.7	16.1	47.0	96.8
Student Achievement	458.5	72.4	353	543
Educational Inequality	87.5	25.1	60	130
Rural Population (%)	35.4	22.4	0.0	64.6

Source: Author's calculations based on World Bank (2024), OECD (2023), and ITU (2023).

The descriptive statistics indicate substantial cross-country variation in digital connectivity, educational performance, educational inequality, and rural population distribution across the selected Asian countries. Internet access demonstrates considerable disparity, ranging from 47.0% to 96.8%, reflecting uneven levels of digital inclusion across national contexts. Student achievement scores also vary substantially, suggesting differences in educational system performance across countries.

Educational inequality indicators reveal persistent disparities in learning outcomes, while rural population distribution highlights structural differences that may influence access to digital and educational resources. These variations support the suitability of the selected countries for comparative macro-level analysis and provide preliminary evidence of uneven digital and educational conditions across Asia.

Table 4. Correlation Matrix of Key Variables

Variable	1	2	3	4
Internet Access	1.00			
Student Achievement	.71*	1.00		
Educational Inequality	-.68*	-.74*	1.00	
Rural Population	-.59*	-.66*	.61*	1.00

Source: Author's correlation analysis based on World Bank (2024), OECD (2023), and ITU (2023).
*Note. *p < .05.*

The correlation analysis indicates moderate to strong associations among internet access, student achievement, educational inequality, and rural population across the selected Asian countries. Internet access demonstrates a positive relationship with student achievement and a negative relationship with educational inequality, suggesting that higher levels of connectivity are generally associated with stronger educational performance and narrower inequality gaps.

Rural population shows a negative association with both internet access and student achievement, while exhibiting a positive relationship with educational inequality. These patterns suggest that structural and geographic disparities remain important contextual factors influencing digital access and educational outcomes across national contexts.

Overall, the findings provide preliminary empirical support for Hypotheses 1 and 3, while also reinforcing the relevance of Hypothesis 5 regarding the structural influence of rural disparities on educational inequality and student achievement.

Table 5. Regression Analysis Examining Structural Associations with Student Achievement

Variable	Beta	Std. Error	t-value	p-value	VIF	95% CI
Internet Access	0.45	0.11	4.09	.006	2.11	[0.17, 0.73]
Digital Infrastructure	0.31	0.09	3.44	.014	2.34	[0.08, 0.54]
Rural Population	-0.28	0.10	-2.87	.028	1.88	[-0.53, -0.03]
Constant	210.6	35.2	5.98	.001	—	—

*Note. *p < .05.*

Table 6. Model Fit Statistics

Statistic	Value
R^2	0.68
Adjusted R^2	0.61
F-statistic	8.42
Model p-value	.009

Multiple regression analysis was conducted to examine the structural associations between digital connectivity, digital infrastructure, rural population, and student achievement across the selected Asian countries. The regression model demonstrated acceptable explanatory capacity (R^2 = .68, Adjusted R^2 = .61), indicating that the included variables accounted for a substantial proportion of variation in student achievement across national contexts.

Internet access demonstrated a positive and statistically significant association with student achievement (β = .45, p = .006), suggesting that countries with higher levels of connectivity generally exhibited stronger educational

performance. Digital infrastructure also showed a significant positive relationship with student achievement (β = .31, p = .014), indicating the importance of broader technological readiness in supporting learning outcomes.

In contrast, rural population demonstrated a negative association with student achievement (β = -.28, p = .028), reflecting structural disparities that may constrain access to educational and technological resources in rural contexts.

Overall, the findings provide empirical support for Hypotheses 1 and 2, while also supporting Hypothesis 5 regarding the structural relationship between rural population and student achievement. Given the exploratory and macro-comparative nature of the study, the findings should be interpreted as indicative of structural associations across national contexts rather than definitive causal relationships.

Table 7. Regression Analysis Examining Structural Associations with Educational Inequality

Variable	Beta	Std. Error	t-value
Internet Access	-0.52*	0.13	-4.00
Digital Infrastructure	-0.29*	0.11	-2.63
Rural Population	0.34*	0.12	2.83
Constant	132.4	28.6	4.63

Source: Author's regression analysis based on global datasets.
*Note. *p < .05.*

Table 8. Model Fit Statistics

Statistic	Value
R^2	0.64
Adjusted R^2	0.57
F-statistic	7.31
Model p-value	.014

*Note. *p < .05.*

Multiple regression analysis was conducted to examine the structural associations between digital connectivity, digital infrastructure, rural population, and educational inequality across the selected Asian countries. The regression model demonstrated acceptable explanatory strength, suggesting that the included variables were meaningfully associated with variations in educational inequality across national contexts.

Internet access demonstrated a negative and statistically significant association with educational inequality (β = -.52, p = .004), indicating that countries with higher levels of connectivity generally exhibited narrower educational disparities. Digital infrastructure also showed a negative relationship with educational inequality (β = -.29, p = .031), suggesting that stronger technological systems may support more equitable educational conditions.

Conversely, rural population demonstrated a positive association with educational inequality (β = .34, p = .026), reflecting persistent structural disparities affecting access to educational and technological resources.

Overall, the findings provide empirical support for Hypotheses 3 and 4, while also supporting Hypothesis 5 regarding the structural relationship between rural population and educational inequality. Consistent with the exploratory and macro-comparative nature of the study, the findings are interpreted as associative cross-country patterns rather than causal relationships.

Table 9. Group Comparison: High vs Low Internet Access Countries

Group	Avg. Student Achievement	Avg. Inequality Gap
High Internet Access (>75%)	502.3	65.4
Low Internet Access (<50%)	438.7	112.6

Source: Author's classification using World Bank internet access thresholds.

The group comparison analysis highlights significant differences between countries with high and low levels of internet access. Countries with higher connectivity demonstrate substantially higher student achievement and lower levels of educational inequality compared with countries with limited internet access. These findings reinforce the importance of digital inclusion in promoting both educational performance and equity. The results provide additional support for Hypotheses 1 and 3, indicating that improved digital access is associated with better learning outcomes and reduced inequality across national contexts.

5.1. Regression Diagnostics and Model Robustness

Regression diagnostic procedures indicated acceptable model stability and no major violations of linear regression assumptions. Residual analyses using histograms, normal probability plots, and Shapiro–Wilk tests suggested acceptable residual normality. Scatterplot inspection of standardized residuals indicated no substantial heteroscedasticity concerns.

Multicollinearity diagnostics further indicated acceptable independence among explanatory variables. All Variance Inflation Factor (VIF) values remained below the recommended threshold of 5.0, while tolerance values exceeded .20, suggesting the absence of severe multicollinearity. These findings support the overall adequacy and robustness of the regression models for exploratory macro-level analysis.

6. Discussion

This study examined the structural relationships between digital connectivity, digital infrastructure, student achievement, and educational inequality across selected Asian countries. The findings indicate that higher levels of internet access and stronger digital infrastructure are generally associated with improved student achievement and lower levels of educational inequality, while higher rural population levels remain associated with lower academic performance and wider educational disparities.

The findings reinforce the central assumptions of Digital Divide Theory, which argues that inequalities in access to information and communication technologies contribute to broader disparities in opportunities and outcomes (Van Dijk, 2020). Across the selected Asian countries, digital connectivity appears to function not merely as a technological resource but as a structural educational condition that shapes students' ability to participate in technology-mediated learning environments. Countries with stronger connectivity and more developed digital ecosystems, such as Singapore, Japan, and South Korea, generally demonstrated higher educational performance and narrower inequality gaps compared with countries facing lower levels of connectivity and broader structural constraints.

At the same time, the findings suggest that access alone is insufficient to guarantee equitable educational outcomes. The distinction between internet access and digital infrastructure highlights the importance of broader institutional and technological readiness in supporting effective digital learning environments. While internet access reflects the availability of connectivity at the household level, digital infrastructure represents the broader ICT ecosystem, including technological capacity, broadband systems, and institutional readiness necessary to sustain educational technology integration. This suggests that educational improvement depends not only on expanding connectivity but also on strengthening the structural conditions that support meaningful digital participation.

The results further demonstrate that rural population remains a significant structural factor associated with both lower student achievement and higher educational inequality. This finding reflects persistent geographic disparities across many Asian educational systems, where rural communities often experience limited technological infrastructure, weaker institutional support, and reduced access to quality educational resources. In several developing contexts, expanding internet availability alone may not fully address educational disparities when broader structural inequalities related to geography, socio-economic conditions, and institutional capacity remain unresolved.

The findings also reveal the multidimensional nature of digital inequality. Consistent with prior literature, the educational benefits of digital technologies appear to depend not only on access itself but also on how digital resources are distributed, supported, and utilized within educational systems. This reinforces arguments that digital inclusion should be understood as a broader socio-technical and institutional process rather than a purely technological issue. Consequently, countries with similar levels of connectivity may still experience different educational outcomes depending on variations in digital governance, educational policy implementation, teacher preparedness, and institutional support systems.

From a comparative policy perspective, the findings suggest that investments in digital infrastructure should be integrated with broader educational reforms aimed at strengthening equity, institutional readiness, and digital capacity development. Policies focused solely on expanding internet access may produce uneven outcomes if technological expansion is not accompanied by improvements in teacher training, curriculum integration, and support for disadvantaged communities. In this context, digital transformation in education should be approached as a systemic and inclusive development strategy rather than a narrowly technological intervention.

Overall, the study contributes to the growing literature on digital inequality by providing comparative macro-level evidence linking connectivity, educational performance, and inequality across Asian educational systems. The findings extend existing research by demonstrating that digital connectivity operates as part of a broader structural ecosystem influencing both the quality and equity dimensions of education within increasingly digital learning environments.

7. Conclusion

This study examined the relationship between digital connectivity, digital infrastructure, and educational outcomes across selected Asian countries using cross-country secondary data analysis. The findings indicate that higher levels of internet access and stronger digital infrastructure are associated with improved student achievement and lower levels of educational inequality, while higher rural population levels are associated with lower academic performance and wider educational disparities.

The results reinforce the view that digital connectivity functions not only as a technological resource but also as a structural component of educational systems that shapes both learning opportunities and equity outcomes. Across diverse Asian contexts, disparities in connectivity and technological readiness remain closely linked to broader socio-economic and geographic inequalities, particularly in rural and underserved areas.

The study contributes to the growing literature on digital inequality by providing comparative macro-level evidence that integrates digital access, educational performance, and inequality within a unified analytical framework. By utilizing internationally comparable datasets from the World Bank, OECD, and ITU, the study highlights how structural differences in digital connectivity correspond with variations in educational outcomes across national contexts.

From a policy perspective, the findings emphasize the importance of expanding equitable digital access alongside broader investments in educational infrastructure, institutional support, and digital capacity development. Efforts to improve educational quality and reduce inequality should therefore extend beyond technological expansion alone and address the wider structural conditions that shape digital participation and learning opportunities.

Overall, the study demonstrates that addressing the digital divide remains essential to advancing both the quality and equity of education systems in Asia, particularly within increasingly digital and technology-mediated learning environments.

7.1. Limitations of the Study

Several limitations should be considered when interpreting the findings of this study. First, the analysis utilized a relatively small country-level sample consisting of selected Asian economies. Although the countries were purposively selected to maximize variation in digital connectivity, educational performance, and socio-economic conditions, the limited sample size constrains statistical generalizability and may reduce the stability of regression estimates compared with large-scale international quantitative studies. However, the study was designed as a macro-comparative and exploratory analysis using nationally aggregated indicators rather than individual-level data, emphasizing structural patterns across educational systems rather than population-level prediction.

Second, the study relied on cross-sectional secondary datasets obtained from international institutions, which limits the ability to establish causal relationships among digital connectivity, educational inequality, and student achievement. The findings therefore reflect comparative associations across national contexts rather than definitive causal effects. In addition, educational outcomes may be influenced by broader institutional, cultural, political, and socio-economic factors that were not fully incorporated into the analytical models. Variables such as national income levels, public education expenditure, governance quality, teacher effectiveness, and broader socio-economic inequality may also contribute to variations in educational outcomes across countries. The exclusion of these factors may introduce omitted variable bias and should therefore be considered when interpreting the findings.

Third, the use of aggregated national indicators may obscure within-country disparities in digital access and educational conditions. Variations across regions, schools, and socio-economic groups within individual countries cannot be fully captured through country-level analysis alone. Consequently, the findings should be interpreted as system-level patterns rather than direct representations of individual student experiences.

Despite these limitations, the study contributes meaningful comparative evidence on the relationship between digital connectivity and educational inequality across diverse Asian educational systems. By integrating internationally comparable datasets from the World Bank, OECD, and ITU, the study provides a broader macro-level perspective on how structural differences in digital access relate to educational performance and equity within rapidly evolving digital learning environments.

8. Recommendations

Based on the findings of this study, several recommendations are proposed to address digital inequality and improve educational outcomes across countries.

First, governments and policymakers should prioritize the expansion of digital connectivity, particularly in underserved and rural areas. Investments in broadband infrastructure, affordable internet access, and nationwide ICT development programs are essential to ensure that all students have equitable access to digital learning resources. Reducing disparities in connectivity is a critical step toward improving both student achievement and educational equity.

Second, educational systems should strengthen digital infrastructure within schools by integrating technology with effective pedagogical practices. This includes providing adequate digital tools, enhancing school-level technological readiness, and ensuring that digital resources are aligned with curriculum and instructional goals. Infrastructure development should be complemented by institutional support systems that facilitate the effective use of technology in teaching and learning.

Third, capacity-building initiatives should be implemented to improve digital literacy among both teachers and students. Training programs focused on digital skills, instructional technology, and the effective use of online learning platforms are necessary to maximize the benefits of digital access. Without adequate skills and competencies, the potential of digital technologies to enhance learning outcomes may remain underutilized.

Fourth, targeted interventions should be developed to address structural disparities affecting rural populations. Policies aimed at reducing geographic inequalities should include increased funding for rural education, improved access to technological resources, and the provision of support mechanisms for disadvantaged communities. Addressing these structural constraints is essential to ensuring that digital technologies contribute to inclusive and equitable education systems.

Future research should further examine the scope of analysis by incorporating additional variables such as quality of education systems, teacher effectiveness, and socio-economic factors. Longitudinal and country-specific studies are recommended to further examine causal relationships and provide deeper insights into the mechanisms through which digital connectivity influences educational outcomes.

Declarations

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Ethical Statement

This study adhered to ethical standards for secondary data research. All data used in the analysis were obtained from publicly available and reputable institutional sources, including the World Bank, OECD PISA, and the International Telecommunication Union (ITU). The datasets are aggregated at the country level and do not contain personally identifiable information. As such, the study posed no risk to human participants and did not require formal ethical approval. Proper citation and acknowledgment of all data sources were maintained to ensure transparency, integrity, and responsible use of data.

Author's Contribution

Author[1]: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Resources, Software, Validation, Visualization, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Author[2]: Investigation, Validation, Resources, Writing – original draft, Writing – review & editing.

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