Home Digital Access as a Channel and Multiplier of Socioeconomic Inequality in Mathematics: Evidence from the Philippines in PISA 2022

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Abstract

The Philippines did not administer the optional PISA 2022 ICT Familiarity Questionnaire, so we examine the one technology measure available for all students — home ICT resources (ICTRES) — as a marker of the digital divide. Using PISA 2022 microdata for the Philippines (analytic N ≈ 5,821 with complete covariates; ten plausible values; eighty Fay balanced repeated replication weights pooled by Rubin's rules), we ask whether home ICT access is associated with mathematics literacy net of socio-economic and school background, and whether it statistically channels and amplifies the socio-economic gap. Home ICT access was strongly associated with mathematics (about 14 score points per index unit, roughly 17 per standard deviation) and robust to a learning-during-disruption block. It statistically accounted for approximately 30% of the association between occupational status and mathematics, and the status-by-access interaction was positive and significant, indicating that the achievement return to access is larger at higher socio-economic status. Home digital access therefore appears to operate as both a statistical channel and a multiplier of educational inequality. The findings provide a pre-generative-AI baseline for understanding how unequal digital resources may shape future technology-supported learning.

Keywords: digital divide; ICT access; mathematics literacy; educational inequality; mediation; moderation; PISA 2022; Philippines

1. Introduction

PISA 2022 documented a broad decline in mathematics performance across participating systems, with the OECD average falling by roughly fifteen score points relative to 2018 — a drop widely attributed to the disruption of the COVID-19 pandemic (OECD, 2023). The 2022 cycle therefore offers an unusually direct view of how systems fared when in-person schooling was interrupted and learning moved, unevenly, into homes.

For the Philippines the gap is stark. Filipino 15-year-olds averaged about 355 points in mathematics against an OECD mean near 472 (OECD, 2023), and the country — which first participated in PISA in 2018 — endured one of the world's longest school closures, sustaining instruction through prolonged distance and modular learning (UNICEF, 2021; DepEd, 2020; Bustillo & Aguilos, 2022). In that context home digital access ceased to be a mere convenience and became a major condition for sustained learning; yet such access remains distributed deeply unequally across Filipino households.

Research on the digital divide has largely asked whether information and communication technology (ICT) predicts achievement (van Dijk, 2005; OECD, 2015). This study asks a more pointed question: is home digital access associated with the transmission and amplification of socio-economic inequality in mathematics? Two commitments frame the analysis. First, because PISA 2022 context data were collected before generative AI entered mainstream classroom use, the technology measure examined here reflects home digital resources rather than AI-tool use; the study therefore stands as a pre-generative-AI baseline of digital inequality. Second, the Philippines did not administer the optional PISA 2022 ICT Familiarity Questionnaire, so the detailed battery of access, quality, and in-lesson-use indices is unavailable for Filipino students. We accordingly concentrate on the single technology measure carried in the core questionnaire — home ICT resources (ICTRES) — and treat it not only as a predictor but as a potential channel and multiplier of the socio-economic gap.

By distinguishing these two roles, the study moves beyond the familiar question of whether ICT matters toward a mechanism-oriented account of how digital access participates in the reproduction of inequality. The findings establish the digital-access baseline that must be understood before AI-supported learning can be equitably scaled.

2. Background

2.1 The digital divide and achievement

Research on the digital divide has progressively widened its lens. Early work framed the divide as a binary of physical access — who is and is not connected (van Dijk, 2005). As connectivity spread, attention shifted to a second-level divide in the skills and types of use that distinguish users even at equal access (Hargittai, 2002), and more recently to a third-level divide in the tangible outcomes people derive from being online, including educational ones (van Deursen & Helsper, 2015; Scheerder, van Deursen, & van Dijk, 2017). A recurring lesson across these levels is that access maps onto existing social stratification: material access, skills, and beneficial use all track socio-economic position (van Deursen & van Dijk, 2019). For schooling, this implies that home digital resources are not a neutral input but a socially patterned one, and that equalising access alone need not equalise outcomes.

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2.2 ICT access and mathematics in PISA

Large-scale assessment evidence on ICT and achievement is mixed and depends heavily on what is measured. The OECD's own synthesis documented systematic differences in ICT access and use by socio-economic status, gender, and location — the digital divide — and cautioned that more technology does not automatically translate into better performance (OECD, 2015). Studies that separate contexts of use find home computer use often more positively associated with achievement than school use (Spiezia, 2010), whereas intensive use of ICT for homework has in several analyses shown null or negative associations with mathematics once background is controlled (Agasisti, Gil-Izquierdo, & Han, 2020). Cross-cycle and cross-country analyses likewise report that the ICT–achievement link varies with how access, home use, and school use are operationalised (Guzeller & Akin, 2014; Skryabin, Zhang, Liu, & Zhang, 2015). Two implications follow: home access and use must be distinguished from leisure use, and the access–achievement relationship should be examined jointly with — not separately from — socio-economic status.

2.3 The Philippine remote-learning context

These general patterns are sharpened in the Philippines. When the pandemic closed schools, the Department of Education sustained basic education through its Basic Education Learning Continuity Plan, relying heavily on modular distance learning in which printed self-learning modules substituted for classroom instruction (DepEd, 2020). The country recorded one of the world's longest periods of in-person school closure, with most learners kept in distance learning for well over a year (UNICEF, 2021); by 2022, learning poverty among Filipino ten-year-olds was estimated near 90% (World Bank, 2022). Because a large share of Filipino households lacked reliable home internet and devices, the shift exposed and deepened the digital divide, particularly in rural and low-income areas (Bustillo & Aguilos, 2022). Mathematics was among the subjects most affected, with students reporting difficulty grasping concepts from modules without teacher mediation (Insorio & Macandog, 2022). For the 15-year-olds assessed in PISA 2022, then, home digital resources index not merely convenience but the practical capacity to continue learning mathematics during a prolonged disruption — making home access an especially consequential marker of educational opportunity in this setting.

3. Conceptual Framework

Mathematics literacy is modelled in relation to home ICT access, net of socio-economic and school background. Two mechanisms are specified on the same access measure, described in associational terms appropriate to cross-sectional data. The channel (statistical mediation) treats home digital access as a pathway linking socio-economic status to achievement: status is associated with access, and access is associated with mathematics, so part of the status–achievement association may operate through access. The multiplier (statistical moderation) asks whether the association between access and mathematics itself depends on status: a positive interaction indicates amplification, in which higher-status students show a larger achievement return to access, widening the gap. This moderation reflects a Matthew-type pattern, in which students with greater socio-economic advantage are better positioned to convert digital access into academic returns. Because ICTRES is partly embedded in PISA's broader socio-economic composites, this study avoids ESCS and the home-possessions index as controls and instead uses occupational status (HISEI) and parental education as less contaminated indicators of socio-economic background; using the composites as controls against the access measure would create a part-whole confound. A secondary learning-during-disruption block situates the analysis in the Philippine school-closure experience.

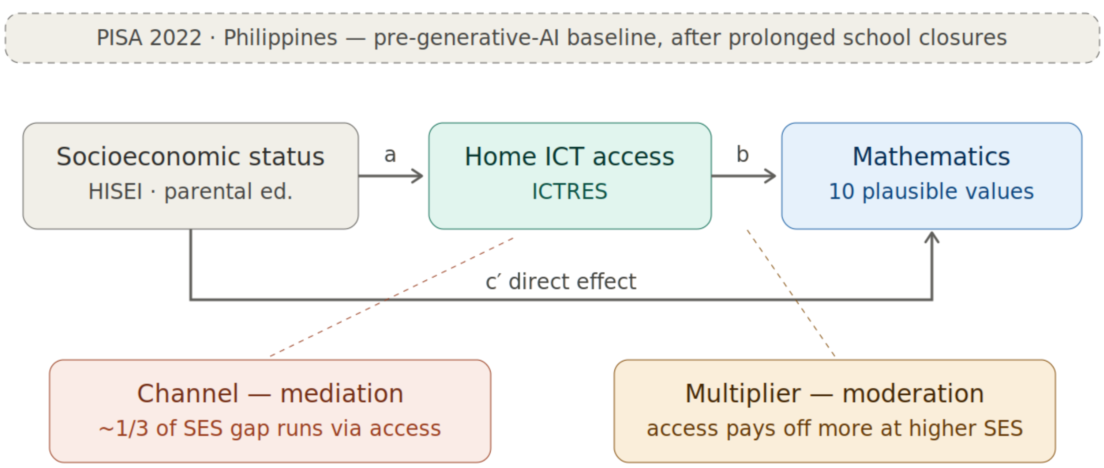

Figure 1. Home digital access as channel and multiplier of socio-economic inequality in mathematics.

This study contributes to PISA-based digital-divide research in three ways. First, it focuses on the Philippines, a lower-middle-income system that experienced prolonged school closures and severe digital inequality, rather than the OECD systems that dominate this literature. Second, it avoids part-whole confounding by separating home ICT resources from the broader socio-economic composites that embed home possessions. Third, it tests home ICT access simultaneously as a statistical channel and a multiplier of socio-economic inequality in mathematics, rather than as a single predictor.

4. Research Questions:

The study is guided by four research questions:

1. Net of socio-economic and school background, is home ICT access associated with Filipino 15-year-olds' mathematics literacy?
2. Does home ICT access statistically mediate the association between socio-economic status and mathematics literacy (the channel)?
3. Does socio-economic status moderate the association between home ICT access and mathematics literacy (the multiplier)?
4. As a contextual sensitivity analysis, were school actions to sustain learning and remote-learning experiences associated with mathematics literacy during the school-closure period?

5. Method

5.1 Data and sample

Data are the PISA 2022 student microdata for the Philippines (computer-based assessment; mathematics the major domain). The Philippines did not administer the optional ICT Familiarity Questionnaire: all option-derived ICT indices (quality, in-lesson use, availability, regulation, self-efficacy) and their underlying items are empty for the full Philippine sample. Home ICT resources (ICTRES), derived from the core questionnaire, is retained. Of 7,193 Filipino students, the core models use the 5,821 with complete covariates (the binding constraints are occupational status and the climate scales, not access). The full-sample weighted mathematics mean is approximately 354, while the analytic-sample mean is somewhat higher because listwise deletion excludes students with missing covariates.

5.2 Measures

Mathematics literacy is represented by the ten plausible values. Home ICT access is the ICTRES index; Filipino students average about 1.5 standard deviations below the OECD mean, itself an indication of the depth of the access gap. ICTRES captures material home ICT resources — the presence of devices and digital resources in the household — not the quality of internet connection, frequency of use, digital skill, instructional use, or AI-tool use. Socio-economic status is operationalised by occupational status (HISEI) and parental education. Because ICTRES is partly embedded in PISA's broader socio-economic composites, this study deliberately avoids ESCS and the home-possessions index as controls and uses these less contaminated indicators instead. Controls are disciplinary climate, teacher support, grade level, sex, and grade repetition. A secondary learning-during-disruption block comprises school actions to sustain learning (SCHSUST), remote-learning resources (LEARRES), self-directed-learning problems (PROBSELF), feelings about learning at home (FEELLAH), and self-directed-learning efficacy (SDLEFF); because these items were rotated across students, they are observed for roughly 3,000 respondents and are treated as exploratory. Because occupational status, parental education, and home ICT resources are correlated socio-economic indicators, their coefficients may shift — including sign reversals arising from statistical suppression — when the measures are entered jointly; such shifts are not given substantive interpretation.

5.3 Analytic strategy

All estimates account for the PISA 2022 design. Population estimates use the final student weight; sampling variances use the eighty Fay balanced repeated replication weights with a Fay factor of 0.5 (variance multiplier 0.05). Every model is estimated on each of the ten plausible values and combined by Rubin's rules, with total variance $U + (1 + 1/M)\cdot B$ for $M = 10$. Three nested models add, in turn, controls and socio-economic status, home ICT access, and the disruption block. Mediation is estimated as occupational status → access → mathematics, with the indirect effect computed as the product of the a- and b-paths and pooled on every replicate and plausible value, yielding design-consistent standard errors without the normal-theory product approximation. Moderation adds a status-by-access interaction, with both terms weighted-mean-centred. Because the disruption items are missing by rotational design (approximately missing completely at random), the third model is reported as a reduced-N exploratory analysis. As the design is cross-sectional, all relationships are interpreted as associations rather than causal effects.

6. Results

Table 1. Weighted descriptive statistics, analytic sample (N = 5,821).

Variable	Mean	SD	N
Mathematics (10 plausible values)	364.6	63.8	5,821
Home ICT access (ICTRES)	−1.48	1.21	5,821
Occupational status (HISEI)	37.37	20.74	5,821
Parental education (years)	12.39	3.46	5,821
Disciplinary climate	−0.17	0.88	5,821
Teacher support	0.55	1.01	5,821
Grade repetition (% yes)	19.3%	—	5,821
Female (%)	46.4%	—	5,821

Note. Weighted by the final student weight. The full-sample weighted mathematics mean is 354; the higher analytic-sample mean reflects listwise deletion of students missing covariates.

Home ICT access was strongly and robustly associated with mathematics literacy. Adding access (Model 2) produced a coefficient of about 14 score points per index unit, roughly 17 points per standard deviation, and raised the mean explained variance from 0.256 to 0.312. Introducing access also reduced the occupational-status coefficient from 0.80 to 0.56, the first indication of a statistical pathway. The negative parental-education coefficient that appears once access enters reflects suppression among the correlated status measures, not a substantive effect, and is not interpreted. A contextual sensitivity analysis that added a reduced-N learning-during-disruption block left the access estimate essentially unchanged (Appendix A: 14.47); within that block, school actions to sustain learning during closures (SCHSUST) showed the strongest positive association with mathematics (8.82).

Table 2. Nested plausible-value regressions of mathematics literacy (pooled; Fay-BRR + Rubin). Coefficient (SE).

Predictor	M1 controls+SES	M2 +access
Intercept	316.69 (7.61)***	359.35 (7.33)***
Occupational status (HISEI)	0.80 (0.06)***	0.56 (0.05)***
Parental education (PARED)	0.57 (0.37)	−0.63 (0.30)*
Home ICT access (ICTRES)	—	14.09 (1.13)***
Disciplinary climate	12.01 (1.14)***	11.19 (1.10)***
Teacher support	5.66 (1.12)***	5.60 (1.09)***
Grade repetition (=1)	−45.40 (3.34)***	−41.79 (3.04)***
Grade fixed effects	included	included
R^2 (mean across PVs)	0.256	0.312
N (complete cases)	5,821	5,821

*Note. *** $p < .001$, ** $p < .01$, * $p < .05$. Grade fixed effects included. R^2 is the mean across the ten plausible values. The reduced-N disruption sensitivity analysis is reported in Appendix A.*

The mediation analysis supported the channel: home ICT access statistically accounted for approximately 30% of the association between occupational status and mathematics (proportion mediated 0.30; indirect 0.24 of a total 0.80), with every path significant.

Table 3. Mediation of the socio-economic association through home ICT access.

Path / quantity	Estimate	SE	95% CI
a: SES → access	0.017	0.001	[0.015, 0.019]
b: access → math	14.09	1.13	[11.88, 16.30]
Indirect (a·b)	0.244	0.027	[0.191, 0.297]

Path / quantity	Estimate	SE	95% CI
Direct (c′)	0.560	0.048	[0.467, 0.653]
Total (c)	0.804	0.058	[0.690, 0.918]
Proportion mediated	0.304	0.027	[0.250, 0.357]

The moderation analysis supported the multiplier: the status-by-access interaction was positive and significant (0.16), meaning the achievement return to home ICT access is larger at higher socio-economic status. In policy terms, home ICT access appears to benefit higher-status students more than their lower-status peers, so access alone may not narrow inequality unless disadvantaged learners also receive the connectivity quality, guidance, and instructional integration needed to convert access into learning.

Table 4. Moderation of the access–mathematics association by socio-economic status.

Term	Estimate	SE	95% CI
Occupational status (HISEI)	0.499	0.045	[0.411, 0.586]
Home ICT access (ICTRES)	14.21	1.11	[12.02, 16.39]
HISEI × ICTRES	0.156	0.039	[0.080, 0.231]

Note. Predictors weighted-mean-centered; pooled across ten plausible values with Fay-BRR standard errors.

7. Discussion

The central contribution of this study is to show that home digital access plays a dual role in educational inequality. It operates as a channel, statistically accounting for roughly a third of the association between socio-economic status and mathematics, and as a multiplier, with a positive status-by-access interaction indicating that the achievement return to access is larger for higher-status students. Mediation alone would echo a well-established finding; the joint channel-and-multiplier pattern on a single access measure is the distinctive claim, and it reframes digital access as a site where inequality is statistically reflected, transmitted, and magnified.

The equity implication is direct. Where access widens rather than narrows the gap, distributing devices without attending to the conditions that let disadvantaged students convert access into learning — connectivity quality, guidance, and instructional integration — risks entrenching inequality rather than reducing it. This message is sharpened by the Philippine context: among the exploratory disruption indicators, school actions to sustain learning during closures stood out as positively associated with mathematics (Appendix A), a policy-relevant signal for the Department of Education and for Region VIII about the value of institutional response when schooling is interrupted.

Several limitations bound these claims. ICTRES is the material slice of socio-economic status and is not cleanly separable from household wealth, so the mediation is best read as a digital-material channel rather than an independent technological effect. The design is cross-sectional, so all relationships are associational; the disruption module is reduced in sample and missing by rotational design; and the data predate generative AI. Because the analytic sample excludes students with missing covariates, the estimates may underrepresent the most disadvantaged students, and the gap between the full-sample and analytic-sample mathematics means (354 versus 365) should be borne in mind when interpreting the results. Within these bounds, the study offers a clear, design-correct baseline of digital inequality in Filipino mathematics learning — one that can inform future analyses of equity in increasingly technology-supported and AI-mediated education.

References

Agasisti, T., Gil-Izquierdo, M., & Han, S. W. (2020). ICT use at home for school-related tasks: What is the effect on a student's achievement? Empirical evidence from OECD PISA data. Education Economics, 28(6), 601–620.

Bustillo, E., & Aguilos, M. (2022). The challenges of modular learning in the wake of COVID-19: A digital divide in the Philippine countryside revealed. Education Sciences, 12(7), 449. https://doi.org/10.3390/educsci12070449

DepEd (2020). Adoption of the Basic Education Learning Continuity Plan for School Year 2020–2021 (DepEd Order No. 012, s. 2020). Department of Education, Republic of the Philippines.

Guzeller, C. O., & Akin, A. (2014). Relationship between ICT variables and mathematics achievement based on the PISA 2006 database. The Turkish Online Journal of Educational Technology, 13(1), 184–192.

Hargittai, E. (2002). Second-level digital divide: Differences in people's online skills. First Monday, 7(4).

Insorio, A. O., & Macandog, D. M. (2022). Video lessons via YouTube channel as mathematics interventions in modular distance learning. Contemporary Mathematics and Science Education, 3(1), ep22001. https://doi.org/10.30935/conmaths/11468

OECD (2015). Students, computers and learning: Making the connection. PISA, OECD Publishing. https://doi.org/10.1787/9789264239555-en

OECD (2023). PISA 2022 results (Volume I): The state of learning and equity in education. OECD Publishing.
OECD (2023). PISA 2022 results (Volume II): Learning during — and from — disruption. OECD Publishing.
OECD (2024). PISA 2022 technical report. OECD Publishing.
Scheerder, A., van Deursen, A. J. A. M., & van Dijk, J. A. G. M. (2017). Determinants of Internet skills, uses and outcomes: A systematic review of the second- and third-level digital divide. Telematics and Informatics, 34(8), 1607–1624. https://doi.org/10.1016/j.tele.2017.07.007
Skryabin, M., Zhang, J., Liu, L., & Zhang, D. (2015). How the ICT development level and usage influence student achievement in reading, mathematics, and science. Computers & Education, 85, 49–58. https://doi.org/10.1016/j.compedu.2015.02.004
Spiezia, V. (2010). Does computer use increase educational achievements? Student-level evidence from PISA. OECD Journal: Economic Studies, 2010(1), 1–22. https://doi.org/10.1787/eco_studies-2010-5km33scwlvkf
UNICEF (2021). Reopening schools safely in the Philippines. United Nations Children's Fund, Philippines. https://www.unicef.org/philippines/reopening-schools-safely
van Deursen, A. J. A. M., & Helsper, E. J. (2015). The third-level digital divide: Who benefits most from being online? In Communication and Information Technologies Annual (pp. 29–52). Emerald.
van Deursen, A. J. A. M., & van Dijk, J. A. G. M. (2019). The first-level digital divide shifts from inequalities in physical access to inequalities in material access. New Media & Society, 21(2), 354–375. https://doi.org/10.1177/1461444818797082
van Dijk, J. A. G. M. (2005). The deepening divide: Inequality in the information society. Sage.
World Bank (2022). The state of global learning poverty: 2022 update. World Bank, UNESCO, UNICEF, FCDO, USAID, & the Bill & Melinda Gates Foundation.

Appendix A. Exploratory disruption sensitivity analysis

Because the learning-during-disruption items were administered to a rotated subset of students, the following model is estimated on a reduced sample (N ≈ 3,000) and is reported as a contextual sensitivity analysis rather than a main result. The home-ICT-access estimate is essentially unchanged from Model 2, indicating that the core findings are robust to inclusion of the disruption block. Among the disruption indicators, school actions to sustain learning (SCHSUST) carries the clearest and largest positive association with mathematics.

Table A1. Learning-during-disruption block (Model 3), reduced sample.

Predictor (Model 3: disruption)	Coefficient (SE)
Home ICT access (ICTRES)	14.47 (1.36)***
School actions to sustain learning (SCHSUST)	8.82 (1.97)***
Remote-learning resources (LEARRES)	2.40 (2.20)
Self-directed-learning efficacy (SDLEFF)	0.17 (2.05)
Controls + SES + grade fixed effects	included
N (complete cases)	≈3,000

Note. Coefficient (SE), pooled across ten plausible values with Fay-BRR standard errors. Two further disruption indices were included in the model but are not tabulated. Controls, socio-economic status, and grade fixed effects included.