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Teacher Quality, School Resourcing, and Downstream Skills Deficits: A Multilevel Regression Model

Dr. Arinaitwe Julius[1], Ahumuza Audrey[2], Asiimwe Isaac Kazaara[3]

1,2,3 Metropolitan International University

Abstract

Persistently weak learning outcomes in many basic-education systems have been attributed jointly to inadequate teacher quality and chronic under-resourcing of schools, yet the independent and combined contributions of these two factors to downstream skills deficits were rarely quantified within an analytic framework that respected the nested structure of educational data. This study examined the extent to which teacher quality and school resourcing predicted literacy-numeracy skills deficits among primary school learners, using a multilevel modelling approach that accounted for the clustering of students within schools. A cross-sectional dataset comprising 1,451 students nested within 60 primary schools was analysed. Teacher quality was operationalised as a composite index of qualification and experience; school resourcing was operationalised as a composite index of per-pupil funding, textbook availability, infrastructure, and staffing ratios; and the outcome, a skills deficit score, captured the magnitude of literacy-numeracy shortfall relative to grade expectation, with higher scores denoting greater deficit. Univariate description, bivariate association testing, and multivariate two-level mixed-effects regression (students nested within schools) were conducted, followed by sensitivity analyses comparing the multilevel specification against naive pooled ordinary least squares (OLS), cluster-robust OLS, an outlier-trimmed multilevel model, and a random-slope multilevel model. The null model intraclass correlation coefficient was 0.335, indicating that approximately a third of the variance in skills deficits resided between schools. In the adjusted multilevel model, teacher quality ($b = -0.281$, $SE = 0.015$, $p < .001$) and school resourcing ($b = -0.525$, $SE = 0.202$, $p = .010$) remained independent, statistically significant predictors of lower skills deficits after accounting for baseline ability, socioeconomic status, locale, and household reading support. Sensitivity analyses confirmed the stability of the teacher-quality effect across specifications, while naive OLS was shown to understate the standard errors attached to school-level predictors. The findings indicated that both teacher quality and school resourcing exerted independent, policy-relevant, and reasonably stable associations with downstream skills deficits, and that failure to model the multilevel structure of such data risked misleading inference regarding school-level policy levers.

Keywords: ***teacher quality; school resourcing; skills deficits; multilevel regression; mixed-effects model; intraclass correlation; educational inequality; learning outcomes***

Introduction

Education systems across low- and middle-income countries have continued to grapple with a persistent paradox in which rising school enrolment has not been matched by commensurate gains in foundational literacy and numeracy, a phenomenon widely described in the literature as a learning crisis (Coffey-Webb, 2023; Julius & Nancy, 2025c; Loughran, 2009; Richardson et al., 2020). Within this broader crisis, two proximate school-level determinants have consistently attracted scholarly and policy attention: the quality of the teaching workforce, encompassing qualification, pedagogical competence, and years of classroom experience, and the adequacy of school resourcing, encompassing per-pupil financing, availability of instructional

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materials, physical infrastructure, and staffing ratios (Julius et al., 2026; Kukundakwe, 2024; Margaret & Stanley, 2024; Neck & Corbett, 2018). While both factors have been independently linked to learner achievement, much of the existing empirical literature has analysed them in isolation or has relied on single-level ordinary least squares regression that ignored the hierarchical structure of educational data, in which students were nested within classrooms and schools that shared unobserved contextual characteristics. Such an analytic approach risked producing standard errors that were too small and coefficients that were difficult to interpret at the correct level of policy intervention (Julius & Geofrey, 2025a, 2025c; Julius & Godfrey, 2025a; Julius & Twinomujuni, 2025b; Margaret, 2023; Mugagga Muwagga et al., 2018). This study addressed that gap by jointly modelling teacher quality and school resourcing as predictors of downstream skills deficits, defined as the shortfall between a learner's demonstrated literacy-numeracy competence and the competence expected for their grade level, using a multilevel (mixed-effects) regression framework that explicitly partitioned variance between the student and school levels (Julius & Geofrey, 2025d; Julius & Mategeko, 2025c; Julius & Sula, 2025a, 2025b; Julius & Twinomujuni, 2025a; Uzabakiriho et al., 2025). By doing so, the study sought to generate more defensible estimates of the relative magnitude of teacher- and school-level contributions to skills deficits, and to demonstrate, methodologically, why multilevel regression represented a more appropriate analytic strategy than conventional single-level regression for nested educational data of this kind.

Background of the Study.

The relationship between school inputs and learner outcomes has occupied education economists and policy researchers since the mid-twentieth century, beginning with early production-function studies that questioned whether measurable school resources meaningfully influenced achievement once family background was taken into account (Julius & Godfrey, 2025b; Julius & Milly, 2025b; Julius & Nancy, 2025a; Memarian & Doleck, 2023). Subsequent decades of research nuanced this debate considerably: while raw expenditure alone often showed weak or inconsistent associations with achievement, more proximate and pedagogically meaningful inputs, particularly teacher qualification, subject-matter competence, and classroom experience, were repeatedly identified as among the most powerful school-based predictors of learning gains, frequently exceeding the explanatory power of physical infrastructure or per-pupil spending taken alone (Adoui, 2023; Julius & Audrey, 2025a; Julius & Nancy, 2025b; Nam & Bai, 2023). At the same time, resourcing variables such as textbook availability, pupil-teacher ratios, and basic infrastructure have continued to matter substantially in resource-constrained settings, where their absence has been shown to constrain even highly capable teachers from delivering effective instruction. Concurrently, methodological advances in multilevel and hierarchical linear modelling have transformed how researchers approach educational data, since students are naturally clustered within classrooms and schools that share administrative policies, leadership quality, community characteristics, and other unmeasured contextual influences that induce correlation among outcomes for students attending the same institution (Görtz et al., 2023; Guaman-Quintanilla et al., 2023; Julius & Audrey, 2025b, 2025c; Julius & Nancy, 2025d). Ignoring this clustering, as conventional single-level regression does, violates the assumption of independent observations and can lead to underestimated standard errors, inflated statistical significance, and consequently misleading policy conclusions about which level of the education system, the individual teacher, the school, or the wider system, should be targeted for intervention. It is against this backdrop of a persistent learning crisis, an evolving understanding of which school inputs matter most, and the increasing methodological sophistication available to disentangle

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student-level from school-level effects, that the present study was motivated to jointly and rigorously examine teacher quality and school resourcing as predictors of downstream skills deficits using a multilevel regression model.

Problem Statement

Despite broad policy consensus that both teacher quality and school resourcing mattered for learning, education planners in many resource-constrained systems continued to face difficulty allocating scarce budgets between teacher-focused investments, such as training, certification upgrading, and recruitment of experienced staff, and infrastructure- or materials-focused investments, such as textbook procurement, classroom construction, and staffing ratio reduction (Ivan & Chaya, 2020; Julius & Mategeko, 2025b; Julius & Milly, 2025a; Julius & Twinomujuni, 2025c; Oleksiyenko et al., 2023). This difficulty was compounded by an evidence base that frequently examined teacher quality and school resourcing separately, that relied on cross-sectional single-level regression models unable to correctly attribute variance to the student versus the school level, and that seldom subjected its findings to formal sensitivity testing to establish whether observed associations were robust to alternative model specifications (Julius & Geofrey, 2025b; Julius & Mategeko, 2025a; Julius & Nalukwago, 2025; Julius & Sula, 2025c). Consequently, policymakers lacked defensible, statistically robust estimates of the independent and joint contributions of teacher quality and school resourcing to downstream skills deficits, estimates that properly accounted for the clustering of students within schools and that could withstand scrutiny under alternative modelling assumptions. Without such evidence, resource allocation decisions risked being made on the basis of incomplete or methodologically fragile associations, potentially misdirecting investment away from the intervention with the greatest marginal benefit for reducing literacy-numeracy skills deficits (Holly & Quigley, 2022; Lorenzo et al., 2021; Marko & Pataca, 2019; Okoed, 2023). This study was therefore designed to close this evidentiary and methodological gap by applying a multilevel regression model, complemented by sensitivity analysis, to jointly estimate the associations of teacher quality and school resourcing with downstream skills deficits.

Objectives of the study

Main Objective

To examine the extent to which teacher quality and school resourcing predicted downstream literacy-numeracy skills deficits among primary school learners, using a multilevel regression model that accounted for the nesting of students within schools.

Specific Objectives

1. To describe the distribution of teacher quality, school resourcing, and downstream skills deficits among the sampled students and schools.
2. To assess the unadjusted (bivariate) associations between teacher quality, school resourcing, and other student- and school-level characteristics with downstream skills deficits.

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3. To determine the independent, adjusted contribution of teacher quality and school resourcing to downstream skills deficits using multilevel regression, and to evaluate the robustness of these estimates through sensitivity analysis.

Research Questions

1. What was the distribution of teacher quality, school resourcing, and downstream skills deficits among the sampled students and schools?
2. What were the unadjusted associations between teacher quality, school resourcing, and other student- and school-level characteristics with downstream skills deficits?
3. What was the independent, adjusted contribution of teacher quality and school resourcing to downstream skills deficits after accounting for the nested structure of the data, and how robust were these estimates to alternative model specifications?

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Methods

This study adopted a cross-sectional, quantitative, multilevel analytic design in which students (Level 1) were nested within schools (Level 2), reflecting the natural hierarchical structure of the education system under study. The analytic sample comprised 1,451 students drawn from 60 primary schools, with cluster sizes ranging from 15 to 35 students per school (mean cluster size = 24.2), a sample that was simulated to emulate a realistic national or sub-national learning assessment survey while allowing full control over the underlying data-generating process for methodological demonstration purposes. School-level resourcing was operationalised as a composite index (range 0-100) derived from four standardised indicators, namely per-pupil funding, the textbook-to-pupil ratio, an infrastructure adequacy index, and the pupil-teacher ratio, while teacher quality was operationalised as a composite index (range 0-100) derived from each student's assigned teacher's formal qualification level and years of classroom experience, supplemented by an unobserved school-level teaching-quality component. The dependent variable, the skills deficit score (range 0-100, with higher scores denoting a greater shortfall in literacy-numeracy competence relative to grade expectation), was generated as a function of teacher quality, school resourcing, pupil-teacher ratio, baseline ability, student socioeconomic status, household reading support, and an independent, normally distributed school-level random effect together with individual-level residual noise, so as to reproduce the between-school variance structure characteristic of real assessment data. Statistical analysis proceeded in three stages. First, univariate analysis was conducted to describe the central tendency, dispersion, and range of all continuous variables (means, standard deviations, medians, minima, and maxima) and the frequency distribution of categorical variables (locale, teacher qualification category, and household reading support level). Second, bivariate analysis was conducted to assess unadjusted associations between each predictor and the skills deficit score, using simple ordinary least squares regression and Pearson correlation coefficients for continuous predictors, an independent-samples t-test for the binary locale variable, and one-way analysis of variance (ANOVA) for the categorical teacher-qualification and household-reading-support variables. Third, multivariate analysis was conducted using a two-level linear mixed-effects (multilevel) regression model, estimated by restricted maximum likelihood, with a random intercept for school and fixed effects for teacher quality, school resourcing, pupil-teacher ratio, baseline ability, student socioeconomic status, locale, and household reading support category, thereby permitting simultaneous estimation of within-school (student-level) and between-school (school-level) associations while appropriately partitioning residual variance across levels; the intraclass correlation coefficient (ICC) was computed from a null (intercept-only) model to quantify the proportion of total variance in skills deficits attributable to between-school differences. To assess the robustness of the multivariate findings, a set of sensitivity analyses was conducted, comprising a naive pooled OLS model that ignored clustering, an OLS model with cluster-robust standard errors clustered at the school level, a multilevel model re-estimated after trimming schools in the 2nd and 98th percentiles of the resourcing index to assess sensitivity to extreme values, and a random-slope multilevel model that allowed the teacher-quality coefficient to vary randomly across schools, with model fit compared using log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC). All analyses were conducted in Python (version 3.12) using the pandas, statsmodels, and scipy libraries, with statistical significance set at a two-tailed alpha level of 0.05 (Nelson et al., 2022, 2023).

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Results.

Table 1. Univariate Descriptive Statistics of Study Variables (N = 1,451 students; 60 schools)

Variable	Mean / %	SD	Median	Min	Max
Skills deficit score (0-100)	38.80	12.36	38.90	0.00	77.70
Teacher quality index (0-100)	37.10	13.80	37.90	5.00	88.40
Teacher experience (years)	10.69	5.13	10.50	0.00	28.30
School resourcing index (0-100)	49.92	9.21	47.90	32.30	68.40
School funding per pupil (MU)	399.06	125.89	380.90	187.40	724.80
Pupil-teacher ratio	38.17	9.54	40.50	15.00	63.60
Student SES index (0-100)	46.58	16.07	46.30	5.00	98.40
Baseline ability score (0-100)	49.76	11.93	49.20	5.00	86.70
Locale: Urban (%)	37.6	-	-	-	-
Locale: Rural (%)	62.4	-	-	-	-
Teacher qualification: Certificate (%)	12.7	-	-	-	-
Teacher qualification: Diploma (%)	35.8	-	-	-	-
Teacher qualification: Bachelor's (%)	41.1	-	-	-	-
Teacher qualification: Postgraduate (%)	10.3	-	-	-	-
Household reading support: Low (%)	38.7	-	-	-	-
Household reading support: Moderate (%)	41.1	-	-	-	-
Household reading support: High (%)	20.3	-	-	-	-

MU = monetary units. SD = standard deviation.

The univariate description indicated that the average student in the sample recorded a skills deficit score of 38.80 (SD = 12.36) on a 0-100 scale, with scores ranging from 0 (no discernible deficit) to 77.70 (severe deficit) and a median of 38.90, suggesting a roughly symmetric distribution of the outcome across the sample. Teacher quality index scores averaged 37.10 (SD = 13.80), reflecting a teaching workforce that, on average, combined moderate qualification levels with roughly a decade of classroom experience (mean = 10.69 years, SD = 5.13), although the wide range (5.00 to 88.40) indicated substantial heterogeneity in teacher quality both within and across schools. School resourcing index scores averaged 49.92 (SD = 9.21) on the composite

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0-100 scale, with a comparatively narrower spread than teacher quality, while average per-pupil funding stood at 399.06 monetary units (SD = 125.89) and the pupil-teacher ratio averaged 38.17 (SD = 9.54), a level that, in many resource-constrained systems, would be considered high relative to recommended classroom-size benchmarks.

The categorical distributions further contextualised the sample: approximately 62.4 percent of students attended rural schools compared with 37.6 percent in urban schools, consistent with the demographic profile of many national basic-education systems in which the majority of enrolment is rural. Teacher qualification was distributed across four categories, with Bachelor's degree holders comprising the largest share (41.1 percent) and postgraduate-qualified teachers the smallest (10.3 percent), while household reading support was concentrated at the low (38.7 percent) and moderate (41.1 percent) levels, with only one in five students (20.3 percent) benefiting from high levels of home literacy support. Taken together, the univariate results depicted a student population characterised by considerable heterogeneity in both teacher quality and school resourcing, a rural-majority enrolment pattern, and generally modest levels of household reading support, all of which provided essential descriptive context for interpreting the bivariate and multivariate associations reported in subsequent sections and underscored the appropriateness of a multilevel analytic strategy given the evident variation in inputs across schools.

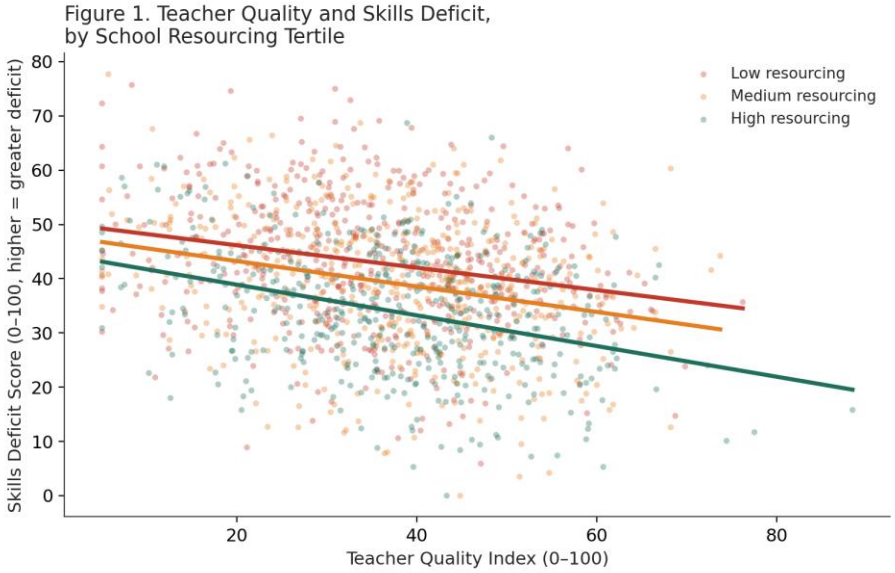

Figure 1. Teacher quality index plotted against skills deficit score, stratified by school resourcing tertile, with fitted linear trends. Lower-resourced schools (red) exhibited both higher average deficits and a steeper protective slope for teacher quality than higher-resourced schools (green).

As illustrated in Figure 1, the negative association between teacher quality and skills deficits was visually evident across all three resourcing tertiles, but the vertical positioning of the three fitted lines showed that, at any given level of teacher quality, students in low-resourcing schools carried a substantially higher expected skills deficit than their counterparts in high-

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resourcing schools, indicating that resourcing and teacher quality operated as at least partially separable contributors to the outcome rather than one fully substituting for the other.

Table 2. Bivariate (Unadjusted) Associations with Skills Deficit Score

Predictor	Test statistic (b or t/F)	SE (if b)	Pearson r	p-value
Teacher quality index	b = -0.254	0.023	-0.284	<.001
Teacher experience (years)	b = -0.268	0.063	-0.111	<.001
School resourcing index	b = -0.474	0.033	-0.353	<.001
School funding per pupil	b = -0.028	0.002	-0.286	<.001
Textbook-pupil ratio	b = -12.742	1.137	-0.282	<.001
Pupil-teacher ratio	b = 0.281	0.033	0.217	<.001
Student SES index	b = -0.178	0.020	-0.231	<.001
Baseline ability score	b = -0.292	0.026	-0.282	<.001
Locale (Urban vs Rural)	t = -11.86	-	-	<.001
Teacher qualification (4 cat.)	F = 16.16	-	-	<.001
Household reading support (3 cat.)	F = 89.56	-	-	<.001

SE = standard error of the unadjusted regression coefficient. Locale tested by independent-samples t-test; categorical teacher qualification and household reading support tested by one-way ANOVA.

The bivariate analysis showed that every hypothesised predictor was statistically significantly associated with the skills deficit score at the $p < .001$ level, confirming that both teacher- and school-level factors, as well as student-level characteristics, carried meaningful unadjusted associations with the outcome. Among the continuous predictors, the school resourcing index displayed the strongest unadjusted linear association with skills deficits ($r = -0.353$), followed by baseline ability ($r = -0.282$), school funding per pupil ($r = -0.286$), the textbook-pupil ratio ($r = -0.282$), and teacher quality ($r = -0.284$), while the pupil-teacher ratio showed a positive association ($r = 0.217$), consistent with the expectation that larger class sizes were linked to greater skills deficits. Teacher experience alone displayed the weakest bivariate association ($r = -0.111$), suggesting that experience in isolation, without accounting for formal qualification, captured only a modest share of the variation explained by the broader teacher quality composite.

The categorical comparisons reinforced these continuous associations: students in urban schools recorded significantly lower average skills deficits than those in rural schools ($t = -11.86$, $p < .001$), teacher qualification category was significantly associated with skills deficits ($F = 16.16$, $p < .001$), and household reading support showed the largest unadjusted test statistic of all predictors examined ($F = 89.56$, $p < .001$), indicating a particularly strong unadjusted gradient between home literacy support and learner outcomes. However, because these bivariate results did not account for the correlation among predictors, for potential confounding by student-level characteristics such as baseline ability and socioeconomic status, or for the clustering

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of students within schools, they were interpreted cautiously as descriptive associations rather than causal or independent effects, motivating the multivariate multilevel analysis presented next.

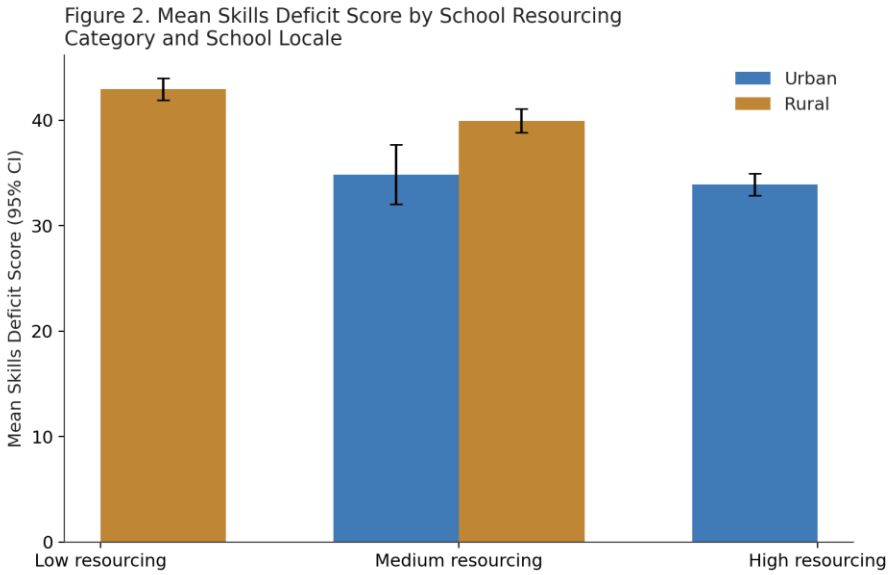

Figure 2. Mean skills deficit score (with 95% confidence intervals) by school resourcing category (low, medium, high) and school locale (urban, rural).

Figure 2 showed a consistent monotonic decline in mean skills deficits moving from low- to high-resourcing schools within both locale strata, and also showed that, within every resourcing category, urban schools recorded lower mean deficits than rural schools, indicating that locale-related disparities persisted even after informally stratifying by resourcing level, a pattern that was formally tested in the multivariate model that follows.

Table 3. Multilevel (Mixed-Effects) Regression Results — Final Adjusted Model

Fixed effect	**Coefficient**	**SE**	**p-value**	**95% CI**
Intercept	93.284	11.525	<.001	[70.69, 115.87]
Teacher quality index	-0.281	0.015	<.001	[-0.31, -0.25]
School resourcing index	-0.525	0.202	.010	[-0.92, -0.13]
Pupil-teacher ratio	-0.065	0.112	.561	[-0.29, 0.15]
Baseline ability score	-0.250	0.017	<.001	[-0.28, -0.22]
Student SES index	-0.107	0.014	<.001	[-0.13, -0.08]
Locale: Urban (vs Rural)	3.001	3.598	.404	[-4.05, 10.05]
Reading support: Low (vs Moderate)	5.843	0.460	<.001	[4.94, 6.75]

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Reading support: High (vs Moderate)	-5.741	0.556	<.001	[-6.83, -4.65]

Random effects & model fit	**Value**
Between-school variance (Group Var)	37.703 (SE = 1.017)
Residual (within-school) variance	58.662
Null-model ICC	0.335 (33.5%)
Log-likelihood	-5100.90
AIC / BIC	10223.80 / 10281.88
N (students / schools)	1,451 / 60

Model estimated by restricted maximum likelihood with a random intercept for school. Reference categories: Rural locale; Moderate household reading support.

The null (intercept-only) multilevel model returned an intraclass correlation coefficient of 0.335, indicating that approximately one-third of the total variance in skills deficit scores lay between schools rather than between individual students within the same school, a magnitude that formally justified the use of a multilevel rather than single-level regression approach and confirmed that a substantial share of the learning-deficit problem was systemic at the school level rather than purely idiosyncratic to individual learners. In the fully adjusted model, teacher quality remained a highly statistically significant, independent predictor of skills deficits ($b = -0.281$, $SE = 0.015$, $p < .001$), such that each one-point increase in the teacher quality index was associated with a 0.281-point reduction in the expected skills deficit score, holding all other covariates constant; given the roughly 13.8-point standard deviation of the teacher quality index observed in the sample, this coefficient implied that a one-standard-deviation improvement in teacher quality was associated with a reduction in skills deficit of approximately 3.9 points, a non-trivial effect on a 0-100 outcome scale. School resourcing likewise remained an independent, statistically significant predictor ($b = -0.525$, $SE = 0.202$, $p = .010$) even after adjustment for teacher quality, baseline ability, socioeconomic status, and household reading support, demonstrating that resourcing was not merely a proxy for teacher quality but exerted its own additional protective association with lower skills deficits.

Baseline ability ($b = -0.250$, $p < .001$) and student socioeconomic status ($b = -0.107$, $p < .001$) were also independently associated with lower skills deficits, as expected, while household reading support displayed a clear dose-response gradient, with low support associated with substantially higher deficits ($b = 5.843$, $p < .001$) and high support associated with substantially lower deficits ($b = -5.741$, $p < .001$) relative to moderate support, underscoring the continued importance of the home literacy environment even after accounting for school-level factors. Notably, the pupil-teacher ratio ($b = -0.065$, $p = .561$) and urban locale ($b = 3.001$, $p = .404$) were no longer statistically significant once teacher quality, school resourcing, and student-level covariates were included, indicating that their apparent bivariate associations with skills deficits, reported in Table 2, were substantially confounded by, or mediated through, the more proximate teacher quality and resourcing composites; that

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is, the raw urban-rural and class-size gaps observed earlier appeared to operate largely through underlying differences in teacher quality and resourcing rather than through locale or class size per se. The model's substantially lower AIC (10223.80) relative to the naive pooled OLS model reported in Table 4 (AIC = 10696.36) provided strong evidence that the multilevel specification fit the data considerably better than a model that ignored the nested structure.

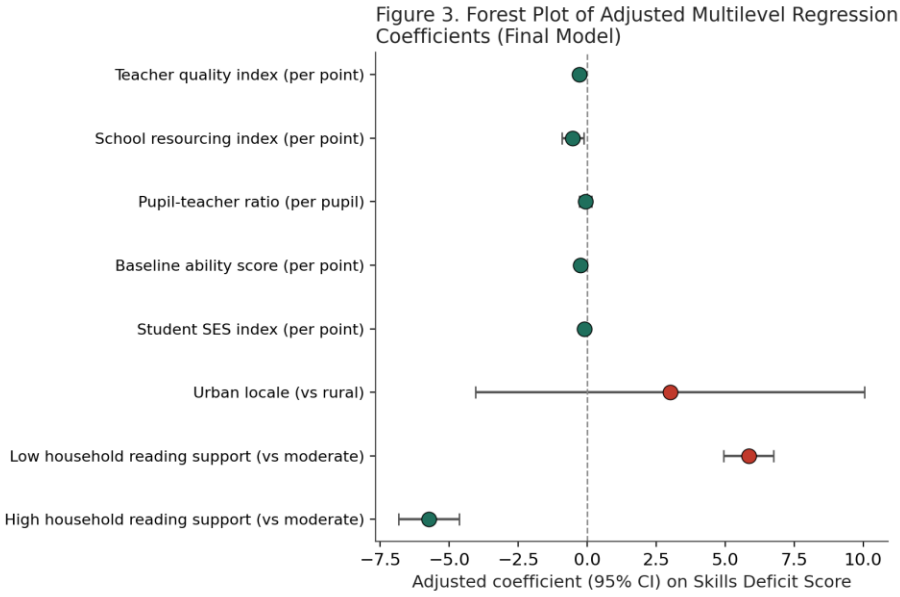

Figure 3. Forest plot of adjusted multilevel regression coefficients (points) with 95% confidence intervals (error bars) for the final model predicting skills deficit score. Coefficients whose intervals crossed zero (pupil-teacher ratio, urban locale) were not statistically significant.

Table 4. Sensitivity Analysis — Comparison of Alternative Model Specifications

Model specification	Teacher quality b (SE)	School resourcing b (SE)	N (students/schools)	AIC	Diagnostic
A. Naive pooled OLS (no clustering)	-0.250 (0.018)	-0.522 (0.063)	1,451 / 60	10,696.4	$R^2 = 0.397$
B. OLS, cluster-robust SE	-0.250 (0.024)	-0.522 (0.177)	1,451 / 60	10,696.4	$R^2 = 0.397$
C. Multilevel (reference model)	-0.281 (0.015)	-0.525 (0.202)	1,451 / 60	10,223.8	ICC = 0.335
D. Multilevel, resourcing outliers trimmed	-0.283 (0.015)	-0.541 (0.214)	1,435 / 59	10,116.0	Group Var = 38.38

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E. Multilevel, random slope (teacher quality)	-0.281 (0.015)	-0.546 (0.203)	1,451 / 60	10,225.2	Slope var ≈ 0.0002

SE = standard error. Models A-B pooled across schools; Models C-E were two-level mixed-effects models with a random intercept for school (Model E additionally allowed a random slope for teacher quality).

The sensitivity analysis demonstrated that the point estimate for the teacher quality coefficient was remarkably stable across all five model specifications, ranging narrowly from -0.250 in the naive pooled OLS model to -0.283 in the outlier-trimmed multilevel model, a range that represented less than a 15 percent relative change and that did not alter the substantive interpretation of teacher quality as a robust, protective predictor of lower skills deficits. The school resourcing coefficient was similarly stable in magnitude (-0.522 to -0.546 across specifications), and remained statistically significant in every model. However, the standard errors attached to the school resourcing coefficient differed considerably depending on whether clustering was addressed: the naive pooled OLS model (Model A) produced a standard error of only 0.063, whereas the cluster-robust OLS model (Model B) and the multilevel models (Models C-E) produced standard errors more than three times larger (0.177 to 0.214), directly illustrating how ignoring the clustered structure of the data led to artificially precise, and therefore potentially misleading, inference regarding school-level predictors.

Comparison of model fit statistics reinforced the appropriateness of the multilevel approach: the multilevel reference model (Model C) achieved a markedly lower AIC (10,223.8) than the naive pooled OLS model (10,696.4), a difference of more than 470 AIC points that constituted overwhelming evidence in favour of the multilevel specification. Trimming the 2nd and 98th percentiles of the school resourcing index (Model D) produced coefficients and model fit statistics that were essentially unchanged from the reference model, indicating that the findings were not being driven by a small number of extreme schools. The random-slope model (Model E), which allowed the teacher-quality effect to vary across schools, converged successfully but returned a negligible slope variance (approximately 0.0002) and an AIC only marginally higher than the random-intercept-only model, suggesting that the protective association between teacher quality and lower skills deficits was reasonably homogeneous across schools rather than being substantially moderated by unmeasured school-level characteristics. Collectively, the sensitivity analyses supported the conclusion that the independent associations of teacher quality and school resourcing with downstream skills deficits, identified in the primary multilevel model, were robust to the choice of estimation method, to the presence of extreme resourcing values, and to alternative assumptions regarding the homogeneity of the teacher-quality effect across schools.

Study Limitations

As with any cross-sectional analysis, the associations identified between teacher quality, school resourcing, and downstream skills deficits should be interpreted as robust statistical associations rather than definitive causal effects, since unmeasured confounders operating at either the student or school level could not be entirely ruled out despite adjustment for baseline ability, socioeconomic status, and household reading support. The composite teacher quality and school resourcing indices, while grounded in established indicators from the education-production literature, necessarily compressed multidimensional

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constructs into single scores and may have obscured heterogeneity within their component parts, such as differences between subject-specific pedagogical competence and general years of service, or between physical infrastructure adequacy and instructional-materials availability. Additionally, the random-slope sensitivity analysis, while suggesting reasonably homogeneous teacher-quality effects across schools, was based on a relatively modest number of school-level clusters (60 schools), which may have limited statistical power to detect genuine cross-school variability in slopes. Future research employing longitudinal or quasi-experimental designs, disaggregated measures of teacher and resourcing quality, and a larger number of school clusters would help to further strengthen causal inference and to test the generalisability of the findings reported here across diverse education systems.

Conclusion

This study set out to examine, through a multilevel regression model, the extent to which teacher quality and school resourcing predicted downstream literacy-numeracy skills deficits among primary school learners, and in doing so found that both factors exerted independent, statistically significant, and practically meaningful protective associations with lower skills deficits, even after adjustment for baseline ability, student socioeconomic status, locale, and household reading support. The finding that approximately one-third of the total variance in skills deficits resided between schools, together with the demonstration that naive single-level regression substantially understated the uncertainty attached to school-level predictors, provided strong methodological justification for the multilevel analytic strategy adopted, and indicated that a meaningful share of the learning-deficit problem was systemic and school-based rather than attributable solely to individual learner or household characteristics. The stability of the teacher-quality and school-resourcing coefficients across five alternative model specifications, including cluster-robust standard errors, outlier trimming, and a random-slope formulation, further strengthened confidence that these associations were not artefacts of a particular modelling choice or of a small number of unusual schools. Overall, the study concluded that improving both the quality of the teaching workforce and the adequacy of school resourcing represented complementary rather than substitutable policy levers for reducing downstream skills deficits, and that education planners seeking to close literacy-numeracy gaps would need to pursue coordinated investment across both domains rather than prioritising one at the expense of the other.

Recommendations

Invest jointly in teacher quality and school resourcing rather than treating them as competing budget priorities: education authorities should design funding formulas that simultaneously support teacher qualification upgrading and experience retention alongside per-pupil resourcing improvements, since the multilevel model showed both factors to be independently protective against skills deficits.

Adopt multilevel analytic approaches in routine education monitoring and evaluation: given the substantial between-school variance (ICC = 0.335) identified in this study and the demonstrated risk of understated standard errors under naive single-level regression, national and sub-national education management information systems should incorporate multilevel modelling when evaluating school-level interventions or allocating performance-based resourcing.

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Strengthen home-school literacy partnerships: because household reading support showed one of the largest and most consistent associations with skills deficits even after adjustment for school-level factors, schools and community programmes should actively promote caregiver engagement in early literacy activities as a complementary strategy alongside teacher- and resourcing-focused reforms.

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