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RESEARCH ARTICLE

Quantifying quality: The impact of measures of school quality on children's academic achievement across diverse societies

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Abstract

Recent decades have seen a rapid acceleration in global participation in formal education, due to worldwide initiatives aimed to provide school access to all children. Research in high income countries has shown that school quality indicators have a significant, positive impact on numeracy and literacy—skills required to participate in the increasingly globalized economy. Schools vary enormously in kind, resources, and teacher training around the world, however, and the validity of using diverse school quality measures in populations with diverse educational profiles remains unclear. First, we assessed whether children's numeracy and literacy performance across populations improves with age, as evidence of general school-related learning effects. Next, we examined whether several school quality measures related to classroom experience and composition, and to educational resources, were correlated with one another. Finally, we examined whether they were associated with children's (4–12-year-olds, $N = 889$) numeracy and literacy performance in 10 culturally and geographically diverse populations which vary in historical engagement with formal schooling. Across populations, age was a strong positive predictor of academic achievement. Measures related to classroom experience and composition were correlated with one another, as were measures of access to educational resources and classroom experience and composition. The number of teachers per class and access to writing materials were key predictors of numeracy and literacy, while the number of students per classroom, often linked to academic achievement, was not. We discuss these results in the context of maximising children's learning environments and highlight study limitations to motivate future research.

KEYWORDS
cross-cultural comparison, formal education, global education, literacy, numeracy, school quality

RESEARCH HIGHLIGHTS

- We examined the extent to which four measures of school quality were associated with one another, and whether they predicted children's academic achievement in 10 culturally and geographically diverse societies.
- Across populations, measures related to classroom experience and composition were correlated with one another as were measures of access to educational resources to classroom experience and composition.
- Age, the number of teachers per class, and access to writing materials were key predictors of academic achievement across populations.
- Our data have implications for designing efficacious educational initiatives to improve school quality globally.

1 | INTRODUCTION

Global participation in formal schooling has rapidly accelerated in recent decades. Since the early 1950s, the percentage of children worldwide attending primary school has risen from around 50%–92% (Imchen & Ndem, 2020). The Sustainable Development Goals (Chasek et al., 2016) represent the global standard for learning and formal education and provide benchmarks for development initiatives worldwide. A core goal of this initiative is to 'ensure inclusive and quality education for all and promote lifelong learning'. This emphasizes formal schooling, with the overall objective that 'all girls and boys' will complete 'free, equitable and quality primary and secondary education' by 2030. Despite this global increase in access to formal schooling, there remains significant inequity in school quality and student learning, however. Over half a billion children and adolescents worldwide are estimated to not reach minimum proficiency in numeracy and literacy, and around 70% of children in low- and middle-income countries cannot read or write at 10 years of age (World Bank, 2022). This is compared to 9% who do not meet this benchmark in high income countries (Imchen & Ndem, 2020). It is thus critical to understand how factors such as school quality and access to education impacts skills such as numeracy and literacy in populations with diverse socioeconomic and educational profiles.

1.1 | The globalisation of formal education

Children's education has long been the focus of policies aimed at promoting future economic productivity and civic engagement (Smithers et al., 2018) and reducing poverty (Lim et al., 2018). Expanding educational attainment in low-to-middle-income countries and low resource communities in high-income countries is an international priority, and within the last 50 years there has been a dramatic increase in access to education. The globalization of formal education—defined as a compulsory, structured education system which typically follows a programme or curriculum (UNESCO, 2011)—provides access to schools and educational resources to communities who historically have not had exposure to this type of structured pedagogical environment. This expansion, including to remote populations, has stimulated cross-cultural research to understand its impact on development (Gurven et al., 2017; Legare et al., 2018). Of particular focus is literacy and numeracy, which are increasingly considered critical skills in a global labour market (Joynes et al., 2019).

Formal education has a particularly strong, positive impact on the development of numeracy and literacy across development, as core skills of focus in early education (Ball et al., 2014; Erbeli et al., 2021). In a growing number of communities worldwide, basic mathematics, reading, and writing skills are critical to access the global economy and thus social mobility (Mok & Neubauer, 2016), as well as prosperity and community integration (Ball et al., 2014; Tout, 2020). Research on Western children shows that with age (and thus increased exposure to formal education) children exhibit a strong increase in literacy and numeracy skills (Aunio & Niemivirta, 2010; Weinberger, 1996). However, the relationship between age and academic achievement is less clear in some countries in the Global South, perhaps because many children develop learning deficits early in schooling and fail to recover (Spaull & Kotze, 2015). In addition, limited opportunities for developing numeracy and literacy skills—an issue in many communities in the Global South due to political, social, cultural, and economic conditions (Sepúlveda et al., 2022)—is detrimental to children's academic progress and future economic and vocational opportunities (Ball et al., 2014).

Intensive short-term interventions aimed at dramatically improving the way a school operates in the US and Europe (often termed school turnaround) have provided promising recent data on school access and quality, and children's academic skill development. In a recent meta-analysis, school turnaround was associated with greater attendance and graduation rates, as well as improved scores on standardised tests (Redding & Nguyen, 2020). Studies outside these regions remain scarce, however, and the limited research that exists generally focuses on years of schooling or highest grade level achieved, rather than educational quality or specific learned skills (Hanushek & Woessmann, 2012). Additional factors that have impeded research beyond high income populations include limited research on the sociocultural contexts of diverse populations. A particular challenge for global efforts to expand educational access is that for many remote communities, such as hunter-gatherer, pastoralist, and subsistence agricultural populations, there remain several obstacles to increasing school attendance for children and caregivers who seek it. These include economic, political, social and cultural barriers, the stigmatisation children face by peers at schools, and disparities between the structured and hierarchical approach of schools versus those of non-hierarchical and transitional communities (Ninkova et al., 2022; Siele et al., 2012). The vast disparity in school quality between populations who have historically recent engagement with and access to formal education further emphasises the need to document how it impacts student learning of critical skills between populations.

Establishing reliable measures of school quality and their association with literacy and numeracy is particularly important for three core reasons. First, as noted, access to formal education is rapidly spreading across the globe. UNICEF aims to provide all children (~3.5 billion individuals) with access to digitised educational resources by 2030. Second, educational philosophies vary dramatically across populations (Tobin et al., 2009). For instance, east Asian countries show a comparatively greater focus on rote learning compared to other nations (Tan, 2011). Western educational philosophy tends to be individualist, and some non-western regions (e.g., sub-Saharan Africa) take a more collectivist approach to education (Enslin & Horsthemke, 2016; Nsamenang, 2005). The extent to which school attendance is compulsory and the frequency (e.g., number of hours per day and days per week) in which children attend differs between nations—and in some cases, between regions and cities within nations. Whether variation in these types of factors shape learning of numeracy and literacy skills remains undocumented and thus poorly understood. Third, quality of schooling and educational resources also varies markedly. Variables related to classroom experience and composition, such as the number of pupils and teachers per classroom, within-class grade ranges as well as teacher experience and attendance, all differ dramatically across populations which have different access to formal education. Likewise, factors associated with the availability of educational resources such as books, stationery or computers also vary substantially between populations. This is particularly important because access to writing materials, such as pens, pencils, and notebooks, and lower student to teacher ratios, improve children's scholastic success because children can better engage in numeracy and literacy-based activities (Hungi & Thuku, 2010) and have more direct teacher engagement (Francis & Barnett, 2019).

Another critical concern is that there are multiple ways to document exposure to schooling and its impact on learning. This includes measures of attendance, performance on numeracy and literacy tasks, collating qualitative data (regarding, for example, attendance or attitudes to education) from caregivers, children, and schoolteachers, as well as school quality assessments (Humphreys et al., 2015). Since understanding which factors significantly impact academic achievement across childhood requires reliable measures of school exposure and quality, it is crucial to assess the validity of difference measures, and indeed whether measures related to classroom experience and composition, as well as measures related to access to educational resources are correlated with one another. Economic research into the effects of education demonstrates that relying solely on years of schooling or highest grade level achieved in cross-cultural comparative research does not provide an adequate understanding of the educational experience for most children worldwide (Lim et al., 2018), thus impeding the ability to assess variation in school quality in diverse educational contexts. Given the range of potential measures used in research, studying school quality can thus be challenging. There are, however, some recommendations that exist and that have been implemented in research (Davis et al., 2020; Mayer et al., 2000; Singer & Braun, 2018). For example, as noted, access to classroom materials (Davis et al., 2021), as well as classroom size for students and teachers (Ehrenberg et al., 2001; Hanushek & Woessmann, 2012) have been linked to children's performance in school (Francis & Barnett, 2019; Hungi & Thuku, 2010).

The aim of this study was to assess the relations between school quality measures related to classroom experience and composition, and access to educational resources, and their impact on academic achievement in 4—12-year-old children across 10 geographically and culturally diverse populations with diverse educational exposure and experiences. The populations that we studied here have historically variable access to formal schooling, with some having generations of access to high quality schools, and others recent and limited access to schools of variable quality. First, we assessed whether children's numeracy and literacy performance across populations improves with age, as evidence of general school-related learning effects. We then examined whether measures of school quality related to classroom composition and experience and amount of access to educational resources were correlated. Finally, we examined whether these measures of school quality predict numeracy and literacy performance.

We predicted that measures of school quality related to classroom experience and composition (e.g., number of grades per school, the number of teachers and students per classroom) would be correlated with one another. We also predicted that age, classroom composition and experience, and amount of access to educational materials would be associated with higher academic performance among children. Given that a large body of literature has reported considerable global variation by gender in access to schooling (Pekkarinen, 2012), educational attainment (Legewie & DiPrete, 2012), and numeracy and literacy (Else-Quest et al., 2010; Voyer & Voyer, 2014), we controlled for gender in all analyses, and we report overall performance on measures of literacy and numeracy by boys and girls across our populations.

TABLE 1 Sample composition by study population organised by population size.

Population (units)	Age (years) Mean	SD	*n*	Gender (% boys) (%)
Manipur, India	8.88	2.50	93	54
Austin (TX), United States	7.45	1.99	62	47
Natal, Brazil	8.98	2.06	118	50
San Cristobal, Colombia	9.64	1.68	100	43
Keningau, Malaysia	8.66	2.01	131	55
Blue Mountains, Australia	9.62	1.87	66	52
Tanna, Vanuatu	8.27	2.27	101	53
Saltpond, Ghana	8.16	2.56	82	52
Motaba River, Republic of Congo	8.29	2.59	53	56
Waoroni, Ecuador	8.57	2.35	83	55

2 | METHODS

Participants included 889 children aged 4–12 years (M = 8.69, SD = 2.23, N = 456 boys) from 10 populations with diverse historical engagement with and current access to formal education, including USA, Colombia, Brazil, Ecuador, Republic of the Congo, Ghana, India, Malaysia, Vanuatu, and Australia. These data were collected as part of a larger project investigating the influence of culture on children's social learning and cognitive development (Burger et al., 2022; Dutra et al., 2022).

Children were recruited in local communities or schools by researchers in each community. Where local literacy rates allowed, caregivers provided written informed consent prior to testing, and where not, verbal consent was obtained. All participants provided verbal assent directly before testing. All sites and methods were included in the ethical approval obtained from the University of Texas at Austin Institutional Review Board (approval number 2017050101). The number of participants from each country ranges from 62 to 131 individuals, or 7% of the sample to 15% of the sample (Table 1). Table 2 provides broader demographic and educational information about each study population.

3 | PROCEDURE

3.1 | Participant surveys

Children and/or their caregivers completed a survey capturing whether and how long children attended school. All surveys were translated by local research assistants to local languages.

TABLE 2 Demographic and educational information for the study sites. Literacy rates refer to national values of those aged 15 and over.

Population	Population size (Approximate)	Population description	Educational information by population
Manipur (India)	2,850,000	Participants were children based in four districts of Manipur, India. Manipur is a state in the north-eastern frontier of India bordering Myanmar. India is a large and diverse country, however, the sampled districts of Manipur– Imphal East, Imphal West, Bishnupur, Churachandpur are representative of north-east India in terms of the cultural commonalities, socio-economic levels, and educational contexts. The study sample comprised of Meeteis, Nagas, and Kukis which are the three broad ethnic communities of Manipur. The latter two are predominantly Christians and are recognised by the Indian government as indigenous tribes. Culturally and linguistically, Manipur shares similarities with East and Southeast Asian countries. Languages spoken by the study sample are mostly tonal Tibeto-Burman languages, but the primary of Manipur language is Meetei-lon. Our sample consists of children from both private and public schools in rural and urban areas and thus broadly representative of other communities in the region	98% of children enrol in school, and 62% secondary school. Education is compulsory between 6–14 years of age and most children attend private schools. Education materials such as textbooks are almost exclusively in English, but children also learn Manipuri and Hindi. The national literacy rate is 77%. The primary language of instruction differs across schools but is either English or Meetei language. However, all school materials are in English except for the language class of Manipuri (Meetei Mayek) or Hindi
Austin (USA)	2,000,000	Austin is a large metropolitan city and is the capital city of Texas, USA. Austin has a demographic makeup that includes 49% white population, 8% black or African American population, and 8% Asian population. Austin contains a significant Hispanic or Latino ethnic minority (33.1%), with 11% of households speaking a language other than English, largely Spanish. Approximately half of the city's population is religious, with most religious persons identifying as Christian. Austin is one of the most educated and wealthy communities in Texas and the US more broadly	95% of the population has completed primary school and 92% of the population has completed secondary school. From six years, school attendance is compulsory, and 95% of children aged six and over attend school. Austin has multiple public and private universities and colleges, and approximately half of adults in Austin have bachelor's degrees and 20% have postgraduate degrees. The national literacy rate is 99% of those 15 and over. There is a strong focus from early childhood on numeracy and literacy. Schools are public, secular, monolingual, co-ed, non-boarding, primary, and typically host hundreds of students. The language of instruction is English
Natal (Brazil)	895,000	Natal is located in the Northeast region of Brazil and is the 19th most populous city in the country. 50% of inhabitants identified as Pardo (various mixed ancestries), 44% as White, 5% as Black, 1% as East Asian, and 0.1% as Natives or Indigenous. Brazilian Portuguese is the official language. Unemployment rate is, at 12%, the sixth highest in the country (in 2022). Natal is representative of other urban areas locally and throughout Brazil	95% attend primary and 82% attend secondary school. There are tax-funded (public) and private schools. School funding comes from all three levels of government. The national literacy rate is 93%. Nationally, Education is compulsory in Brazil between ages 7 and 14. Schools were located in Natal. They were public, secular, monolingual, co-ed, and not boarding. Though secular, Brazilian schools and businesses commonly celebrate Christian dates. Primary language of instruction was Brazilian Portuguese. Schools in Natal generally hold several hundred pupils. Adults average 12 years of education
San Cristobal (Colombia)	404,350	San Cristobal is an area within the capital city of Colombia, Botaga, which itself has over 7 million inhabitants. San Cristobal is a relatively poor area of the city. Many families have migrated into the area from rural, conflict-ridden parts of Colombia within the last few decades. Approximately 90% of the population are Colombian, and 10% Venezuelan (recent immigrants). Spanish is widely spoken. San Cristobal is not particularly representative of neighbouring communities, as it is near the centre of the biggest city in the country (Bogota), leading to high proportions of internally displaced people, recent immigrants, and commuters	93% attend primary school, and 77% attend secondary school, nationally. The national literacy rate is 96%, and national compulsory school begins at six years. Data was collected at a public school in San Cristobal, inner Bogota. The school has approximately 1,000 pupils, and the instruction language is Spanish. Most adults have secondary level education, with minorities of only primary level (more in older generations) and university level (more in younger generations)

(Continues)

TABLE 2 (Continued)

Population	Population size (Approximate)	Population description	Educational information by population
Keningau (Malaysia)	150,000	Keningau is situated in a valley surrounded by mountain ranges and rain forests, situated about 65 miles away from the capital city of the state of Sabah (formerly known as North Borneo), East Malaysia. It is the fifth biggest township of the state. Basic public infrastructures such as health clinics, banks, restaurants, and supermarkets are available. Keningau is ethnically and linguistically diverse. Residents predominantly speak either Malay or Mandarin. Various temples, churches, and mosques are available in the region. The majority of indigenous people are Christian but also practise traditional rituals. The study sample is representative of peri-urban townships in the area, but not of bigger cities	95% attend primary school, and 91% attend secondary school. Schools of various sizes are widely available. Small private institutions are also widely available to offer after-school or holiday tutoring. Some schools operate in shifts due to limited space. School funding comes from the state, but policies are overseen by the school district board. Most children start attending Kindergarten from 4 or 5 years of age, but all children must attend primary school by the age of 7 years. The national literacy rate is 95%. The schools that participants attended are public and secular, promoting multilingual education. Most of them come from an indigenous, Christian background. The primary language of instruction is Bahasa Malaysia (national language), however, the schools also instruct in English or Mandarin Chinese, depending on subjects taught or the theme of school activities. In the area, most adults have high school level education
Blue Mountains (Australia)	72,000	Participants were based in the Blue Mountains region, which is a rural/suburban area approximately 100 kilometres from metropolitan Sydney, in the state of New South Wales (NSW). It is less linguistically diverse than Australia on average, and 90% of homes in the Blue Mountains only speak English at home, while 67.6% is the rate for NSW overall, and 72% for Australia	99% of children attend primary school, and 92% attend secondary school. All children must attend school between the ages of 6–16. Literacy and numeracy are top priorities for the Department of Education of NSW for all public schools. The study school hosts 250 pupils, and is a public, secular, monolingual, co-ed, day-school. The language of instruction is English. The national literacy rate is 99% of those 15 and over and most adults have advanced diplomas or bachelor's degrees
Tanna (Vanuatu)	32,000	Participants were children based in three regions in Tanna, Vanuatu. Tanna is a small island in the island archipelago of Vanuatu. Some individual Ni-Vans still adopt a very traditional way of living in Kastom villages (Inkunala, and Lenaualaul), while others adopt a less traditional lifestyle and reside in the main town on the island (Lenekel). This community consists of urban and rural participants and is representative of other communities in the region	Around 78% of children attend primary school, and 48% secondary school. Schools are partially funded by government and religious organizations, and still developing in many areas. Around 65% of primary schools teach in English and 35% teach in French. Currently, primary education is not compulsory. The literacy rate is 88% of those aged 15 and over. For the Tafea Province, in which the community is located, about 40% of adults have no school education, 39% have a primary school education, and 18% have up to a secondary education. Less than 1% of adults go on to tertiary or vocational school
Saltpond (Ghana)	25,000	Participants were Akan children from Saltpond, a small city that functions as the capital of the Mfantsiman Municipal District, in the Central Region of South Ghana. The Mfantseman Municipal, with its Administrative Capital Saltpond, forms part of the 22 Metropolitan Municipalities and District Assemblies (MMDAs) in the Central Region and one of the 260 MMDAs in Ghana. Ethnically, 94% of the population is Akan and the primary language is the Akan language (or Fante). The religious composition is distributed among Christians, Methodists, Protestants, and Muslims. This community is representative of other local ones, though Saltpond has a strong focus on petroleum extraction whereas other communities have a greater focus on fishing industries	Locally, 73% of children aged 6—11 years attend primary school and 57% attend secondary school. The literacy rate is 79%. Education is compulsory from four years until 15 years of age. The community contains several primary and junior primary schools, as well as two secondary schools. Schools in Saltpond are public, and methodist supported. The primary language of instruction is English and Fante and pupils are predominantly Fante

(Continues)

TABLE 2 (Continued)

Population	Population size (Approximate)	Population description	Educational information by population
Motaba River (Republic of the Congo)	10,000[1]	Bandongo children were recruited from a small multiethnic village in the Likouala region of the Republic of the Congo, home to ~400 people. Bandongo people primarily speak Lingala and Bondongo, however some French phrases or nouns are occasionally used. Their social structure exhibits strong age and sex hierarchies. The study village is very representative of other Bandongo communities	65% of children in the Republic of the Congo attend primary school and 18% attend secondary school. The national literacy rate is 77%. Education is not enforceable where the research took place, so is dependent on family support. For those that attend, school in the area begins at 6 years. In the study population, there is one primary school, but attending secondary school requires relocating to another village. The school is located on the edge of a small village in the Likoulala region of the Republic of the Congo. It is a public, secular, co-ed, non-boarding primary school that is primarily taught in French—despite French being a seldom used language outside the classroom. Most students were Bandongo, although precise numbers are unavailable. In the study area, most adults have not completed primary school
Waoroni (Ecuador)	2,000[2]	Data was collected in Keweriono, Wentaro, Nenkipare, Tiguino and Bataboro communities, which are all relatively remote. All communities are primarily ethnically and culturally Waorani, and all also have some intermarriage with Amazonian Kichwa groups. In multicultural families, the Waorani language (Wao Terrero) is typically dominant. Almost all individuals under the age of 40 are fluent in Spanish, or a local dialect of Spanish. Approximately half of the population identifies strongly as Christian (Evangelical or Catholic). Waorani society remains highly egalitarian in nature, and high value is placed on individual autonomy. The communities involved in this study very representative of other Waorani communities in the region, however they are quite different from colonist communities, and are very different from urban centres	91% of children attend primary school and 85% attend secondary school, nationally. The national literacy rate is 94%. Schools are located in clear spaces, close to the forest. Schools in the sample area were public schools operating under the intercultural and bilingual framework (undersecretary of education). This is one modality that can be selected in public education as an alternative to the Hispanic education system. These schools typically have teachers from indigenous nations in Ecuador. School sizes range from 10–80 pupils, and the pupil demographic is primarily Waorani, and some Amazonian Kichwa. Spanish is the primary language of instruction, although Waorani teachers in primary school often teach in Wao Terrero or explain Spanish concepts in the local language. In high school, Wao Terrero is sometimes taught. All adults except elders over the age of 80 years old have had some experience with formal education. Most adults have had at least three years of primary school, but very few adults over the age of 45 have completed high school

[1]Based on estimates from researchers and local residents.
[2]Based on ethnographic data (Cardoso et al., 2012).

3.2 | School quality measures

Researchers collected data on the following measures of school quality, either through direct observation or by interviewing teachers or school staff members. Our measures of school quality were adapted from previously established measures which have, in some studies, previously been shown to be important predictors of academic achievement and performance (Burchinal et al., 2010; Davis et al., 2020; Mayer et al., 2000): (1) the number of students per classroom, (2) the number of grades or years per school, (3) the average number of teachers per class, and (4) the amount of writing materials available to students (pens, pencils, notebooks). Variables 1–3 are related to classroom experience and composition, and variable 4 is related to the availability of educational resources. Access to writing materials per classroom was assessed by researchers at each site and reported on a scale from 0 to 3, where:

0 = No materials available

1 = Very little available (i.e., fewer pencils, pens, paper than students in the classroom)

2 = Some/adequate supplies available (i.e., just enough pencils, pens, paper for each student in the classroom)

3 = Many supplies available (i.e., more than enough pencils, pens, paper for each student in the classroom; other writing materials such as markers, crayons, etc available to students in classrooms)

3.3 | Academic knowledge assessment

The academic knowledge assessment task was a multi-stage assessment of literacy and numeracy, and a similar version has been used with the Tsimané of Bolivia (Davis & Cashdan, 2019). It was based on the Iowa Test of Basic Skills (Hoover et al., 2003), which has been used in multiple cultures (Clifford et al., 1989), but adapted for this project to focus on literacy and numeracy. Both the literacy and numeracy components had four separate stages. The assessment was structured such that if a participant failed to meet criterion of a given stage of the numeracy or literacy components (see below), testing was ceased at that point for that component. The order in which the literacy or numeracy components were presented was counterbalanced across ages and gender, and the task was presented in the language that the participant was taught in school (though in populations where the predominant community dialect is different to the school language, the instructions were given in the former).

3.4 | Literacy component

The academic knowledge assessment literacy component contained four subsections of increasing difficulty: letter identification, word identification, sentence reading, and reading comprehension.

3.4.1 | Letter identification

In the first stage, letter identification, participants were presented with a sheet of 14 randomly located different letters, with four black and white pictures spaced amongst them. The experimenter pointed to one of these letters (out of 10 consecutively) and asked the participant, 'What letter is this?' Participants were required to verbally identify each letter the experimenter pointed at. If a participant answered incorrectly for three consecutive problems within the letter identification stage, testing for the literacy section was ceased.

3.4.2 | Word identification

The second stage of the literacy component was a word identification task. Participants were presented with a sheet of 14 randomly located different but culturally accessible words (e.g., goat, sun, house) with four black and white pictures spaced amongst them. The experimenter pointed to one of these words (out of 10 consecutively) and asked the participant, 'What word is this?', and the participant was required to identify this word. If a participant answered incorrectly for three consecutive problems within the word identification stage, the literacy section was ceased.

3.4.3 | Sentence reading

The third stage was sentence reading. The experimenter presented each participant with a list of ten sentences of increasing length (e.g., 'Rain falls down', 'Trees can grow very tall'). The experimenter uncovered one sentence at a time and asked the participant to read the sentence aloud. For all sites, testing for the literacy section was ceased if participants stopped reading on two consecutive sentences. For the first four sites where data was collected (India, Congo, Vanuatu, Ghana), it was also discontinued for children who made mistakes on three consecutive sentences.

3.4.4 | Reading comprehension

The fourth stage was reading comprehension. Participants read a short one-paragraph story to themselves before answering four multiple choice questions about events and characters in the story.

3.5 | Literacy component scoring

Scores were calculated for each of the four stages independently and overall. One point was given for a correct response on the letter and word identification stages such that each had maximum scores of 10. For the sentence reading, participants were given two points if a sentence was read with no mistakes, one point if one or two mistakes were made on a sentence but the participant did not stop reading, and no points if the participant made two or more mistakes and/or stopped reading the sentence (maximum score of 20). Mistakes were classified as instances when the participant said the wrong word even if they later corrected it, if they read the words out of order, and/or they made an extreme mispronunciation. Stops were classified as instances when the participant stopped reading the sentence before it was completed (i.e., the participant did not continue the sentence at any later point). Participants were given one point per correct answer on the reading comprehension stage (maximum score of 4). Combining stages, participants could score a maximum of 44.

3.6 | Numeracy component

The numeracy component also consisted of four subsections: a counting task, number identification, addition and subtraction mathematical problems, and multiplication/division problems.

3.6.1 | Counting task

The first stage of the numeracy component was a counting task. Participants were presented with a sheet of different quantities of six neutral stimuli images (i.e., one insect, two fish, three trees and so on). The experimenter pointed to one of these images and asked the participant, 'How many [stimulus] is this?'. If a participant was incorrect on three consecutive problems within the counting stage, testing for the numeracy section was ceased. There was a maximum of four questions.

3.6.2 | Number identification

The second stage was number identification, in which participants were presented with a sheet of 14 randomly located unique numbers. The experimenter pointed to one of these numbers (out of 10 consecutively) and asked the participant, 'What number is this?' Participants were required to identify this number. If a participant was incorrect for three consecutive problems within the number identification stage, testing for the numeracy section was ceased. The maximum score was 10.

3.6.3 | Addition/subtraction problems

The third stage consisted of addition/subtraction problems. The experimenter presented the participant with a sheet of paper with six addition/subtraction puzzles which varied in difficulty (i.e., $2+2 = x$, to $72-37 = x$) and said, 'Okay, now let's try these. Fill in the answers to the problems on this sheet. Try as many as you can, even if you are unsure what the right answer is. You can use this sheet to figure out the answers. Let me know when you've finished.' Participants were given up to six minutes to complete them and there was a maximum score of six.

3.6.4 | Multiplication/division problems

The multiplication/division stage was the same as the addition/subtraction, except children were presented with five multiplication/division puzzles (i.e., $35/7 = x$, $29 \times 53 = x$) and were given five minutes to complete them. If a participant was incorrect on four problems within the addition/subtraction or multiplication/division stages, testing for the numeracy section was ceased.

3.7 | Numeracy component scoring

As with the literacy component, scores were calculated for each of the four stages independently and overall. One point was scored for each correct answer on the counting and number identification tasks, giving maximum scores of 4 and 10, respectively. One point was also given for each correct response for the addition/subtraction and multiplication/division problems, giving maximum scores of 6 and 5, respectively. Combining each stage of the numeracy component, participants could score a maximum of 25.

4 | STATISTICAL METHODS

Data analysis and visualisation was conducted in R version 2022.02.0 using the packages ggplot2 for data visualisation (Wickham, 2009) and lmer4 for model development and analysis (Bates et al., 2015). We begin by describing the sample characteristics and descriptive statistics of key variables by gender, controlling for age (Table 3). We then used linear models to assess performance on numeracy and literacy by age, controlling for gender. We next examined whether the different measures of school quality are correlated with one another using Pearson's partial correlations. Finally, we considered whether measures of school quality predict performance on measures of numeracy and literacy using general linear models and mixed effects models. To account for the non-independence of learning institutions across populations, each population was entered as random effects into mixed effects models. Model comparisons provided estimates of the relative quality for statistical models, and best-fit models are reported in the results.

TABLE 3 Descriptive statistics on key variables.

	Total sample		
Variable (units)	Mean	SD	*n*
Age (years)	8.69	2.23	889
Schooling (years)	3.96	2.55	554
Literacy component			
Letter identification (0–10)	7.97	3.52	889
Word identification (0–10)	5.00	3.31	742
Sentence reading (0–20)	15.05	6.33	557
Reading comprehension (0–4)	2.79	1.19	484
Numeracy component			
Counting task (0–4)	3.67	0.83	884
Number identification (0–10)	9.00	2.38	855
Addition/subtraction (0–6)	3.18	2.00	753
Multiplication/division (0–5)	1.87	1.51	424
School quality measures			
Number of students per class	25.36	13.82	832
Number of grades per school	7.56	3.68	788
Number of teachers per class	1.28	0.41	889
Writing materials (0–3)	1.13	0.92	889

5 | RESULTS

5.1 | Literacy and numeracy

Figure 1 shows the distribution in performance on literacy tasks by gender, including letter identification, word identification, sentence reading, reading comprehension. Though boys showed slightly higher averages on letter identification, there was no significant effect of gender ($\beta = -0.45$, $p = 0.06$, 95% *CI*: −0.91, 0.02), but there was a significant positive age effect ($\beta = 0.53$, $p < 0.001$, 95% *CI*: 0.44, 0.63). Boys did not outperform girls on any other literacy task (all *p*s > 0.05). However, there were positive associations between age and word identification ($\beta = 0.91$, $p < 0.001$, 95% *CI*: 0.78, 1.04), sentence reading ($\beta = 1.25$, $p < 0.001$, 95% *CI*: 1.00, 1.50), and reading comprehension

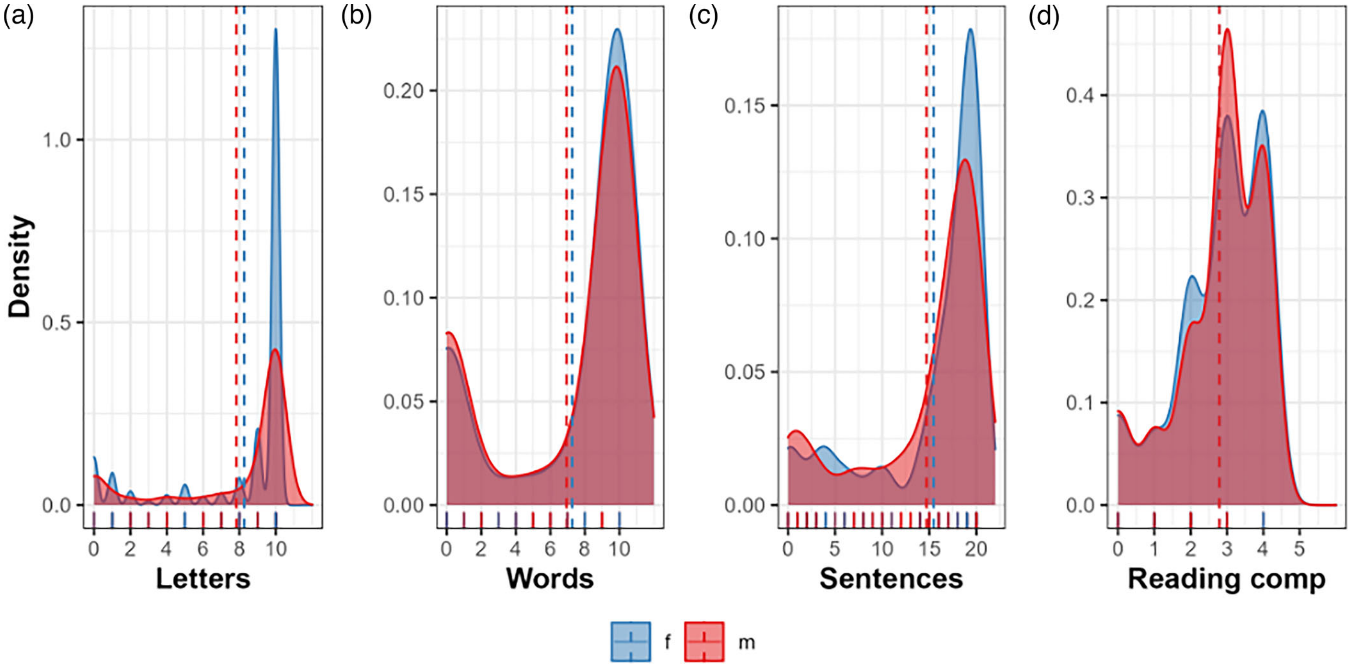

FIGURE 1 **Patterns in literacy scores**. Density plots display distribution of boys' and girls' (A) letter identification ($N = 889$), (B) word identification ($N = 742$), (C) sentence reading ($N = 557$), and (D) reading comprehension scores ($N = 484$). Sample sizes decreased as task difficulty increased. Rug marks on the X-axis indicate the range of average performance.

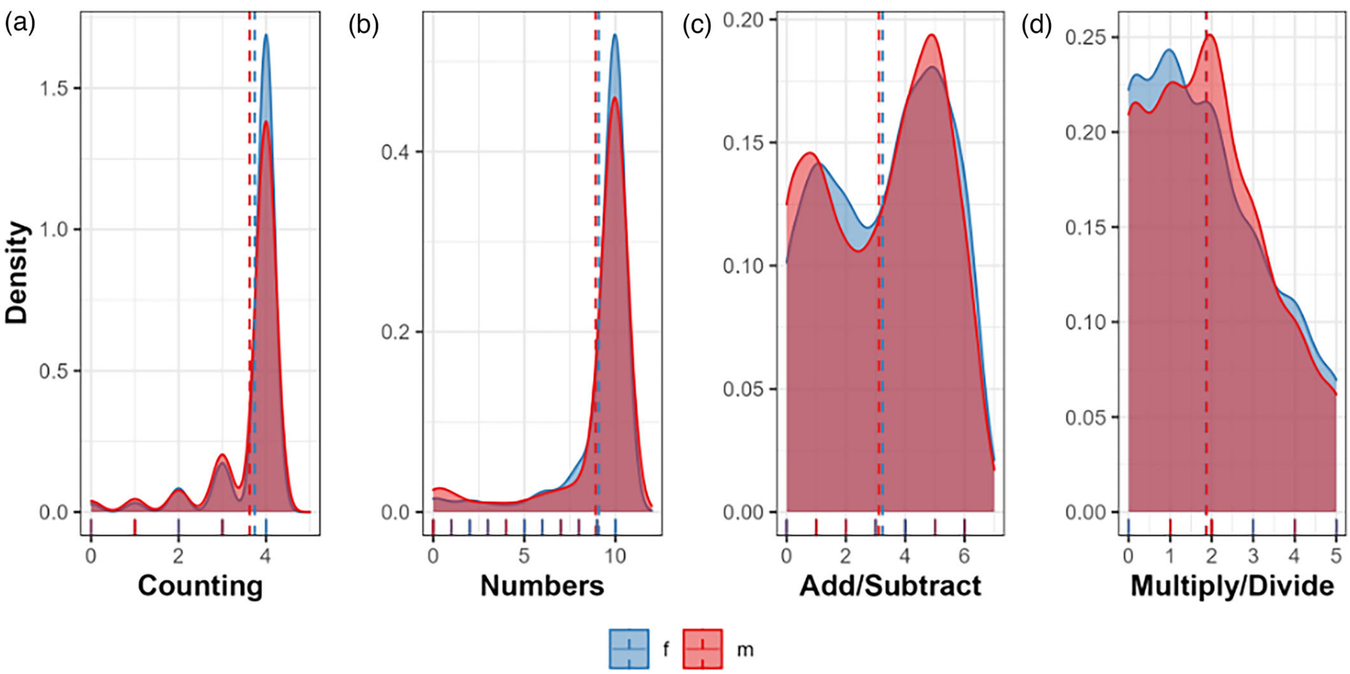

FIGURE 2 **Patterns in numeracy scores**. Density plots display distribution of boys' and girls' (A) counting ($N = 884$), (B) number identification ($N = 855$), (C) addition and subtraction ($N = 753$), and (D) multiplication and division ($N = 424$). Sample sizes decreased as task difficulty increased. Rug marks on the X-axis indicate the range of average performance.

($\beta = 0.20$, $p < 0.001$, 95% *CI*: 0.15, 0.26). Thus, literacy ability improved with age.

Figure 2 displays the distribution of performance on the numeracy tasks. Boys and girls performed similarly on the counting task ($\beta = -0.06$, $p = 0.31$, 95% *CI*: -0.17, 0.05) and number identification ($\beta = -0.07$, $p = 0.69$, 95% *CI*: -0.41, 0.27) when controlling for age (there were positive age effects; $\beta = 0.13$, $p < 0.001$, 95% *CI*: 0.11, 0.16 and $\beta = 0.37$, $p < 0.001$, 95% *CI*: 0.29, 0.44, respectively). Older

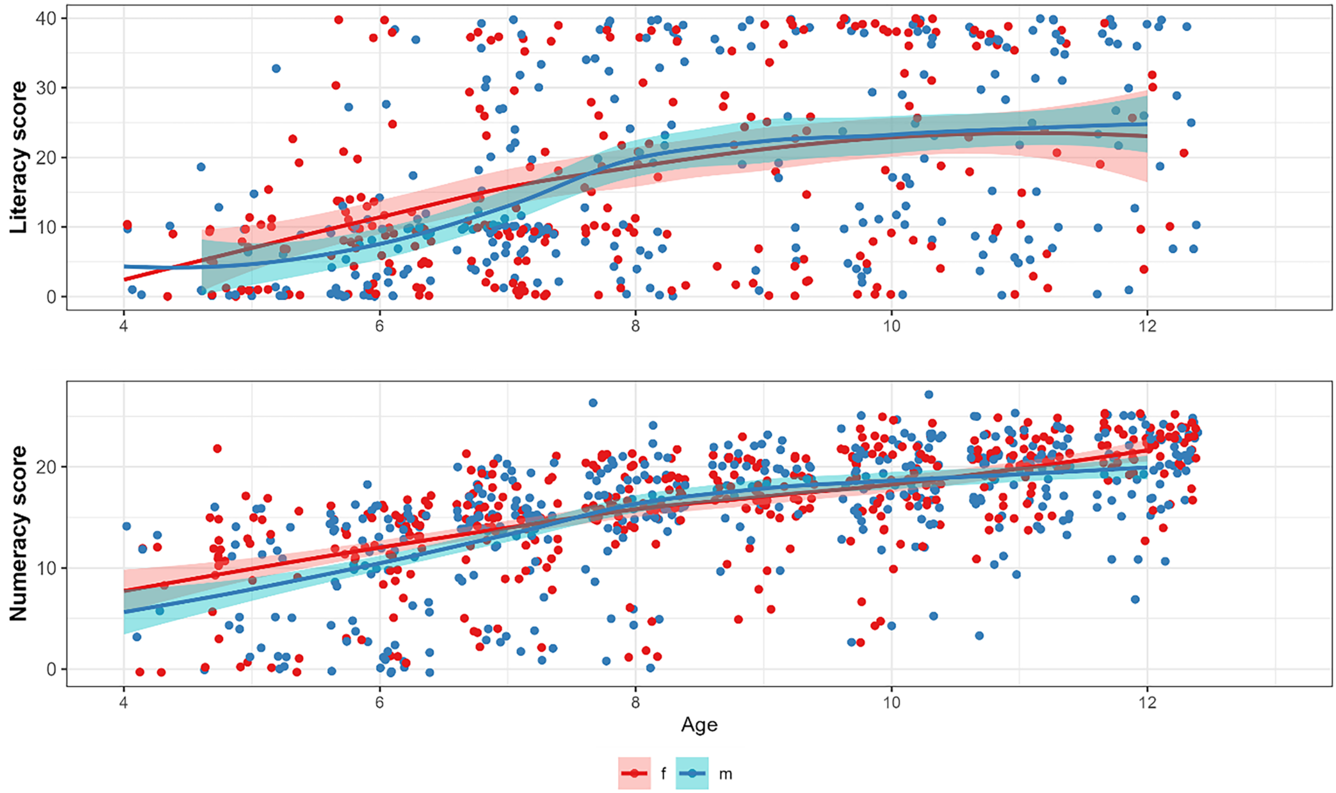

FIGURE 3 **Patterns in literacy and numeracy scores across the sample.** Scatterplots of literacy score (top row) and numeracy score (bottom row) from 10 countries ($N = 889$). Both scatterplots are fitted with a smoothing spline for each sample of boys and girls. Shaded areas represent 95% CIs.

children performed better on the addition and subtraction ($\beta = 0.55$, $p < 0.001$, 95% *CI*: 0.49, 0.62) and multiplication and division ($\beta = 0.43$, $p < 0.001$, 95% *CI*: 0.36, 0.50) tasks, when controlling for sex ($\beta = -0.15$, $p = 0.26$, 95% *CI*: -0.40, 0.11 and $\beta = 0.03$, $p = 0.83$, 95% *CI*: -0.24, 0.30, respectively). Figure 3 displays literacy and numeracy composite scores (all sub-components combined) by age and gender, across populations.

6 | RELATIONS BETWEEN MEASURES OF SCHOOL QUALITY

Measures of school quality related to classroom composition and experience included the number of grades per school as well as the number of students and teachers per class. The amount of writing materials available to students reflected access to resources. Pearson partial correlations between these variables are shown in Table 4. Controlling for age and gender, the amount of writing materials available to students positively correlated with the number of grades per school, and the number of teachers and students per class. The number of teachers per class and the number of grades per school were negatively correlated with one another. The number of students per class was negatively correlated with the number of grades per school and positively correlated with the number of teachers per class (see Table 4 for full correlations between school quality variables).

TABLE 4 Pearson's pairwise partial correlations between measures of school quality ($N = 889$).

	# Students per class	# Grades per school	# Teachers per class	Writing materials
# Students per class	1			
# Grades per school	-0.51^{o}	1		
# Teachers per class	0.13***	-0.18***	1	
Writing materials	0.26***	0.36***	0.21***	1

Statistical significance markers: ^{o} $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$.

We next examined the association between performance in literacy and numeracy with each measure of school quality, individually, controlling for age and gender. Children at schools with fewer grades demonstrated higher performance in literacy ($\beta < 0.001$, $p = -6.43$, 95% *CI*: -7.01, -5.85) and numeracy ($\beta = -2.16$, $p < 0.001$, 95% *CI*: -2.35, -1.97). Likewise, classrooms that had more teachers was also associated with higher literacy ($\beta = 7.16$, $p < 0.001$, 95% *CI*: 6.27, 8.05) and numeracy ($\beta = 2.64$, $p < 0.001$, 95% *CI*: 2.35, 2.93). Greater availability of writing materials in the classroom also positively predicted children's literacy and numeracy ($\beta = 8.93$, $p < 0.001$, 95% *CI*: 7.83, 10.04 and $\beta = 3.43$, $p < 0.001$, 95% *CI*: 3.07, 3.77, respectively). However, there was no association between the number of students per

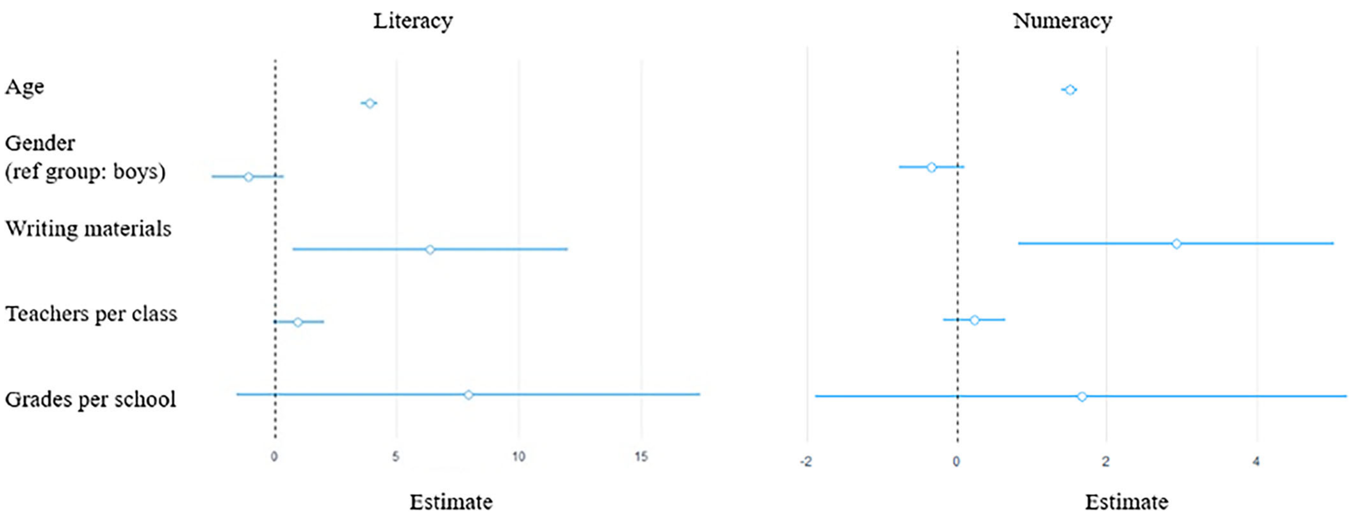

FIGURE 4 Performance in literacy (left) and numeracy (right) as a function of school quality measures which were significant predictors, controlling for age and gender. Performance in literacy and numeracy improves with increased access to writing materials. There was a moderate positive effect of the number of teachers in the classroom on literacy performance.

classroom and literacy and numeracy performance ($\beta = 0.01$, $p = 0.78$, 95% *CI*: −0.06, 0.07).

The three significant school quality predictors (teachers per classroom, grades per school, and writing materials) were then entered into a mixed effects model. Each model included the demographic measures (age and gender) and school quality, with population entered in as a random effect (Figure 4). For the linear mixed models, which included population as a random effect, models for literacy and numeracy scores included age, gender, grades per school, writing materials, and teachers per classroom. Access to writing materials predicted greater performance in both literacy and numeracy (Figure 5). There was a moderate effect of the number of teachers per classroom on academic performance. The number of grades per school was positively associated but did not significantly predict literacy or numeracy when other measures of school quality were included in the model (Table 5).

TABLE 5 Best-fit linear mixed effects and general linear models for literacy (left column) and numeracy (right column) by age, gender, and measures of school quality. Both mixed effects models include random intercepts for sample population.

	Dependent variable: Performance on literacy and numeracy	
	(Mixed effects) β (95% CI) Literacy	(Mixed effects) β (95% CI) Numeracy
Age	3.89*** (3.55, 4.23)	1.50*** (1.40, 1.61)
Gender (Ref group: boys)	−1.09 (−2.55, 0.38)	-0.33 (−0.77, 1.60)
Writing materials	6.37* (1.78, 4.76)	2.93** (1.18, 4.67)
Teachers per class	0.93° (0.01, 1.85)	0.23 (−0.11, 0.58)
Grades per school	7.93 (−0.03, 1.85)	1.66 (−1.28, 4.61)
Constant	-32.40 (−44.21, −20.59)	−4.96 (−9.33, −0.60)
Observations	785	778
AIC	5937.11	4020.36

Statistical significance markers: ° $p \le 0.1$; * $p \le 0.05$; ** $p \le 0.01$; *** $p \le 0.0$

7 | DISCUSSION

Recent decades have seen a marked increase in school attendance across the world, driven by global initiatives aimed at providing all children access to education. Yet, most of what we know about the impact of education on children's learning is based on populations with multi-generational access to schools, funded and institutionalised at national levels. Research conducted in high-income countries has shown that school quality has a marked, positive impact on the development of academic skills such as numeracy and literacy. However, we have little understanding of how to optimally measure school quality and key predictors of academic achievement outside of high-income populations. Moreover, there are several quantitative and qualitative measures of school quality used in the literature, and the validity of using specific measures to examine how it affects academic achievement remains underspecified. Here, we addressed these issues by investigating whether (1) there are age-related improvements in academic achievement as evidence of general schooling effects, (2) school quality measures correlate with one another, and (3) they predicted children's numeracy and literacy performance in 10 populations with diverse educational profiles. Our results show that improved

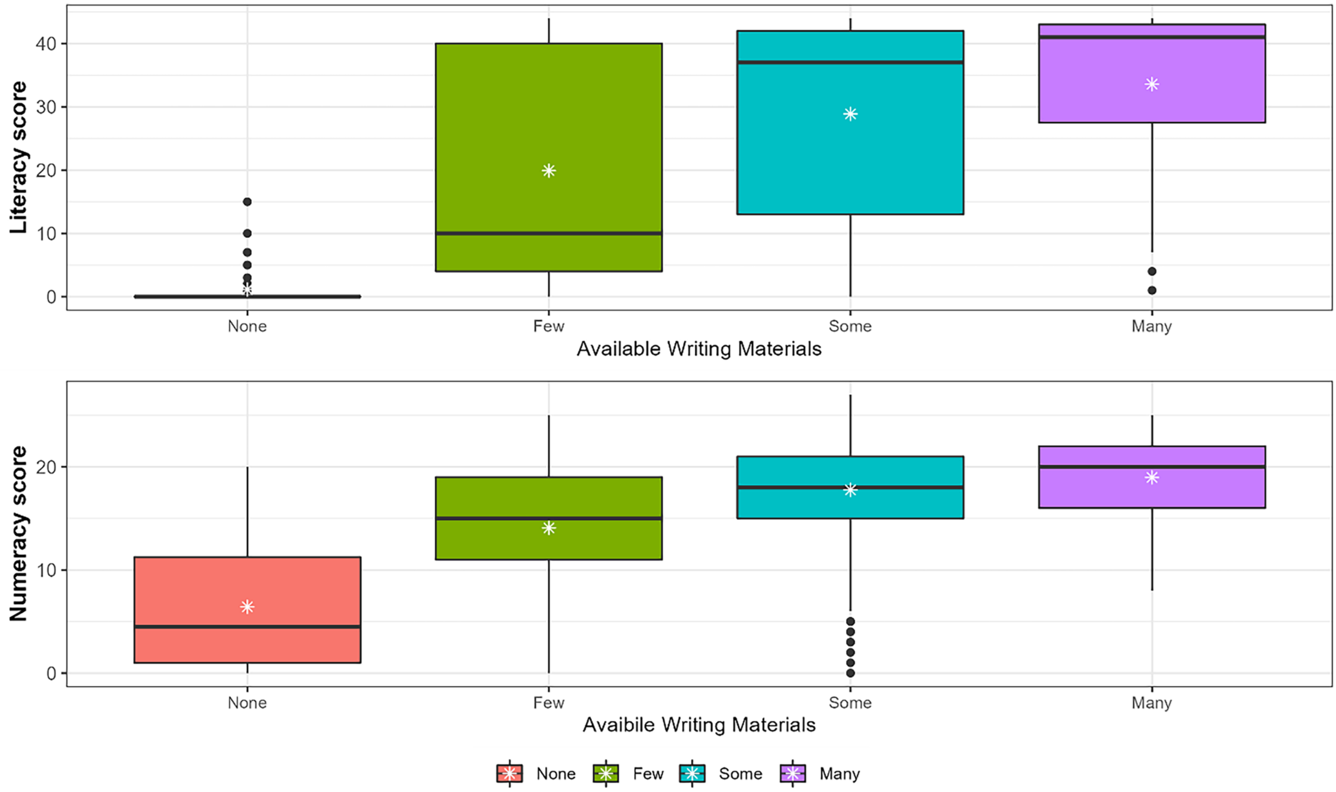

FIGURE 5 **Writing materials effects on literacy and numeracy scores**. Box plots showing mean and first and third quartiles for literacy scores (upper plot) and mathematics (lower plot). $N = 889$.

academic achievement is a product of the educational conditions in which school-derived skills are taught and exercised, and that measures of school quality correlate with one another, within and across domains.

7.1 | Were there age-related and gender differences in academic achievement?

Across populations, age was a strong, positive predictor of literacy and numeracy for boys and girls. This provides evidence for general positive schooling effects on learning critical school-related skills. Research on western populations has shown that as children get older and progress through schooling systems, their literacy and numeracy performance strongly improves (Aunio & Niemivirta, 2010; Weinberger, 1996). However, other research in some Global South populations suggests that the relationship between age and academic achievement is complex and not as strong (e.g., South Africa: Spaull & Kotze, 2015), potentially because varying school quality and wide wealth distribution means many children acquire learning deficits early and fail to catch up (Alcott & Rose, 2017; Spaull & Kotze, 2015). By demonstrating that, across multiple populations, with increased schooling exposure their literacy and numeracy performance significantly improves, our data suggests formal education is critical to the development of key academic skills.

7.2 | Which measures of school quality were associated with one another?

Across our school quality variables, measures of access to educational resources (i.e., the amount of writing materials available to students) and measures of within class composition (the number of grades per school and number of students and teachers per class) were positively correlated. Thus, larger schools, with larger class sizes and more teachers tended to be better resourced in terms of writing materials. We also found that variables related to classroom experience including the number of teachers per class (which was a key predictor of academic achievement) and the number of students per class were positively correlated, such that classes with more students had more teachers. Conversely, the number of teachers and students per class were negatively correlated with the number of grades per school, where schools with fewer grades had more teachers and students per classroom.

Although researchers have used a range of different measures of school quality, the validity of using diverse variables is not always clear, particularly because there is little information on whether variables expected to be associated with one another are across populations. Whether measures of school quality can be adopted in populations with diverse approaches to, and engagement with, formal education has been the subject of recent debate, with some suggesting that cross-cultural approaches to assessing factors that predict scholastic success should be limited to 'culturally-similar' countries (Singer &

Braun, 2018). An important component of reliability is that measures within domains are associated with one another, and this is particularly important in global education research, given the range of potential measures of school quality available. Our finding that the variables assessed here were correlated with others in similar domains in 10 culturally diverse countries contribute to this discussion, potentially suggesting that they are valid indicators of school quality and can be used as reliable measures to examine academic performance in children and scholastic development.

7.3 | Which school quality measures predicted numeracy and literacy?

We found that, across our study populations, more teachers per classroom was moderately, positively associated with literacy performance. Previous research, largely in western populations, has shown that reducing the student to teacher ratio in the classroom improves academic success and provides population level health benefits (Adeyemi, 2007; Francis & Barnett, 2019; Harfitt, 2012; Muennig & Woolf, 2007; Pedder, 2006). Our findings showed that reducing the teacher to student ratio positively impacts literacy in diverse populations. This is ostensibly because reducing the student-to-teacher ratio allows children to more often, and directly, engage with teachers and educational resources and, conversely, reduces the load on teachers, leading to better learning environments (Francis & Barnett, 2019). Previous research in the west suggests that smaller classrooms may be more important at younger ages, but that the relationship between class size and academic achievement is not straightforward and requires more research given it is an expensive policy change (Ehrenberg et al., 2001; Jepson, 2015). Our data indicates that population composition and subsistence levels also play a role. We thus argue that more qualitative data should be considered in global educational research and that a one-size-fits all may not be optimal making policy decisions on class size.

We also found that increased access to writing materials had strong, positive effects on children's numeracy and literacy across populations. Previous research in a range of countries in Southern Africa showed that greater access to writing materials was positively associated with scholastic success because children can more readily engage in reading and writing to practise and improve their academic skills (Hungi & Thuku, 2010). Here, we extend these findings to 10 globally and culturally diverse populations. Using pens and pencils to write also improves young children's motor and visuospatial skill development—which themselves have been linked to academic performance—through drawing, writing numbers and letters and counting items on paper (Cameron et al., 2016).

Conversely, the number of grades (years) per school did not significantly impact numeracy and literacy in our study, when controlling for other measures of school quality. Given that most of our populations had similar known compulsory starting ages for school it is possible that the grade ranges did not vary meaningfully across our sample. Further research with populations who have larger variation in these variables is needed to verify these findings.

7.4 | Study implications

Our data contribute to discourse on methods to develop optimal educational environments, enabling children to reach their scholastic potential. In many remote communities—particularly some hunter-gatherer, pastoralist, and subsistence agricultural populations—there are many barriers precluding consistent access to formal schooling for those who seek it (Ninkova et al., 2022; Siele et al., 2012). These include economic, social, and cultural barriers, the stigmatisation children face by peers at school, and disparities between the structured and hierarchical approach of schools versus those of non-hierarchical and transitional communities (Ninkova et al., 2022; Siele et al., 2012). Our data suggests that in multiple populations who follow diverse educational approaches, access to educational resources and student-teacher ratios are crucial factors impacting core academic skills. With widespread initiatives targeting increased access to formal schooling across the globe, our findings emphasise, where possible, the need to equip schools with basic resources and to consider the number of teachers to maximise children's academic achievements. In the face of resource constraints, policymakers could consider alternative strategies to improve children's learning experiences. For instance, some research suggests that, in cases where reducing class size is unachievable, enabling teachers to work more intensively with small groups may provide some similar benefits to children's academic achievement (Sharples et al., 2019).

7.5 | Study limitations

A key limitation was that we cannot directly assess underlying mechanisms underpinning our findings. For example, because our data were collected among school children, we could not address effects of experiences outside of formal schooling on the development of academic skills. Similarly, although we found that more teachers positively impacted academic performance, our dataset did not allow us to examine why. Longitudinal research directly examining the underlying reasons that factors such as classroom size impact numeracy and literacy in diverse populations is an important next step for future research.

Another limitation is that we have solely focussed on the relationship between school quality and performance on scholastic measures (numeracy and literacy). While this was our core aim, it does not allow assessment of other cognitive skills which may be positively or negatively affected by formal education. It is important to consider, for example, how teacher quality, or overall attendance to formal schooling, may impact wider cognitive and social development in children in populations that have historically had little engagement with it. For example, in many countries in the Global South, attending school can contribute to local knowledge loss (by removing children from core community activities) and disrupt language development (for instance, when the language used in schools differs from children's mother tongues; Ninkova et al., 2022). Documenting whether, and how, attending school affects cognitive and social development is important to provide a holistic understanding of how formal education shapes children's lives.

There are also trade-offs associated with different kinds of cross-cultural comparisons. *Far comparisons* entail comparing populations that differ along many kinds of economic, social, cultural, linguistic, and educational variables. The advantage of this kind of comparison is that it allows researchers to study variation that exists in some populations and not others. The disadvantage, however, is that the amount of variability makes it difficult to isolate the impact of particular sources of variation. *Close comparisons* entail comparing populations that are similar according to most kinds of variables but differ in respect to a core variable of education (e.g., educational access). The advantage of close comparisons is that it allows researchers to test the impact of single variables on key outcomes of interest. The disadvantage is that it only affords to study the range of variation that exists within largely similar populations. In this study, however, we used both far and close cultural comparison, including high-, middle-, and low-income populations and small-scale societies. This allowed us to sample a wide range of globally representative variation in school access and quality that would not be possible by limiting our sampling to only far (or only close) comparison.

8 | CONCLUSION

Literacy and numeracy are increasingly considered fundamental skills of the 21st century, and, across the globe are associated with a range of important life outcomes such as workplace achievement (Kuncel & Hezlett, 2010) and social mobility (Mok & Neubauer, 2016). Our findings have important implications for efforts by international agencies to improve numeracy and literacy in children. We find that age was a strong predictor of academic achievement, suggesting that formal education has a marked impact on numeracy and literacy in populations with diverse educational profiles. We also find that several measures of school quality are correlated in multiple populations, providing key information on the validity of using different assays as reliable measures of the quality of schooling. Our data also reveal that more teachers in the classroom and increasing access to educational materials such as books, pens, pencils, and notepads has a marked positive impact on children's numeracy and literacy in populations varying in overall exposure to formal education, and their approaches to schooling.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests.

DATA AVAILABILITY STATEMENT

Due to ethical reasons, this data is available from the corresponding author upon reasonable request.

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