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Variation in Mathematics Performance: A Multilevel Analysis With Student and School's Characteristics

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Abstract

Using data from the Trends in International Mathematics and Science Study (TIMSS), this study examines the student and school characteristics that contribute to students' mathematics performance in early elementary school in Chile. Previous research has separately analyzed the association of student and school factors with mathematics performance. This study uses multilevel modeling analyses to account for those factors together and understand variability within and between schools. The sample in this study was 6,322 fourth grade students from 169 schools. The students' mean age was 10.07 (*SD* = 0.50); 49.6% were girls. The results from this study show that student characteristics, such as the home mathematics environment, helped explain the variation between schools more than within schools. These findings highlight the importance of considering contextual factors, such as parent–child math interactions, when developing education policy and intervention to foster students' mathematics skills.

Keywords

mathematics, student characteristics, school characteristics, home mathematics environment, TIMSS

Non-Technical Summary

Why was this study done?

This study explored the factors that influence fourth-grade students' math performance in Chile. We looked at both individual characteristics, like early math skills reported by parents and the home mathematics environment, and school characteristics, such as math resources and socioeconomic status, to understand differences in math achievement. The data came from a large international study called TIMSS.

What did the researchers do and find?

This study shows how student and school characteristics help explain variation between schools and how each characteristic relates to students' mathematics performance. We found that a child's home math environment, including how often parents engage in math-related activities, plays a big role in their math performance. Schools also matter: students in schools with fewer resources and more socioeconomically disadvantaged students tend to perform worse in math. Additionally, boys performed better than girls in math, showing a gender gap that needs attention.

What do these findings mean?

Supporting families in fostering early math skills and providing more resources to schools serving disadvantaged students could help close the achievement gap and improve outcomes for all children. This study highlights the importance of focusing on early learning and creating equitable educational opportunities to help students succeed in math.

Highlights

- The study demonstrates that the home mathematics environment (HME) significantly explains variance in fourth-grade mathematics performance in Chile, particularly across schools, emphasizing the role of parent-child interactions in fostering early math skills.
- Multilevel analyses reveal that school characteristics, such as socioeconomic disadvantage and resource availability, are key predictors of between-school differences in math performance, with disadvantaged schools displaying consistently lower outcomes.
- Gender disparities are evident, as boys significantly outperform girls in mathematics, highlighting the persistent gender gap in Chile's educational system.
- Parental education and early reported math skills positively predict fourth-grade math outcomes, underscoring the importance of early learning experiences and socioeconomic factors in shaping academic success.

Mathematics is one of the STEM skills that has become fundamental in the 21st century (Stehle & Peters-Burton, 2019); which are skills necessary for students to solve problems and thrive beyond the school context. Although mathematics is an essential ability, results from the Trends in International Mathematics and Science Study (TIMSS) show that 21 of 49 countries performed significantly lower than its fourth-grade benchmark in mathematics (Mullis et al., 2020). One predictor of students' mathematics performance in elementary school is students' early mathematics skills (e.g., Nguyen et al., 2016). Given that the development of mathematics skills starts in the early years, it is important to understand factors that might foster those early skills.

According to ecological theories of development, the home and school contexts are among the most critical environments for fostering children's learning development (Bronfenbrenner & Morris, 2007). Vygotsky's social development theory argues parents and teachers, as more knowledgeable others, provide children with support and resources to accomplish new skills (Vygotsky, 1978). This study examines student and school characteristics that contribute to variations in mathematics performance in early elementary school. Although previous studies have separately analyzed the association of student and school characteristics with students' mathematics performance, no previous studies have looked at those variables simultaneously. In this study, we accounted for school and student factors to understand variability within and between schools using a multilevel approach. We explored these factors through a large representative sample from Chile.

Chile is relevant as a case study because it is among the 10 countries with the lowest mathematics performance in the TIMSS. Thirty percent of Chilean students do not have basic mathematics knowledge in fourth grade—the international median is 8%—and only 1% of Chilean students reach the advanced benchmark (Mullis et al., 2020). Students at the low international benchmark level have some basic mathematics understanding. For example, they can add and subtract whole numbers, do some multiplication with a one-digit number, and solve simple word problems. Students at the advanced benchmark can think and apply their knowledge in complex situations. For example, they can understand fractions and decimals, interpret data to solve problems, and find more than one solution (Mullis et al., 2020). In addition to the low performance, Chile has a segregated educational system with high variation between schools (OECD, 2016). Thus, Chile is an appropriate case study for understanding students' mathematics performance by including student and school characteristics in the same model.

Mathematics Skills

Children's mathematics skills predict later reading outcomes at the school level even better than early reading abilities do (Clements & Sarama, 2011). They are also associated with elementary school outcomes (Duncan et al., 2007) and high school achievement (National Mathematics Advisory Panel, 2008). Students' mathematics abilities in high school, in turn, are associated with college matriculation and later earnings (National Mathematics Advisory Panel, 2008). However, mathematics gaps are already present in preschool, which suggests mathematics skills develop prior to schooling. Kindergarten children from low-income and disadvantaged backgrounds are at a higher risk for low mathematics performance (Jordan et al., 2009; Siegler et al., 2012). Given the importance of early mathematics skills, a proxy variable of children's early mathematics skills (i.e., parents' perfections of their children's skills) was included as a predictor in our analyses.

A construct that has been used to explain children's early mathematics gaps is the home mathematics environment (HME; e.g., Melhuish et al., 2008; Napoli & Purpura, 2018; Susperreguy et al., 2020). The HME encompasses parent–child interactions and activities that focus on numbers, such as numeral names, counting, and combining or comparing magnitudes; activities related to spatial thinking, such as puzzles, building blocks, and spatial relation talk using specific words (e.g., above and between); and patterning activities, such as repeating shape patterns (e.g., Zippert & Rittle-Johnson, 2020). A growing body of research has examined the association between the HME and children's mathematics skills (see Daucourt et al., 2021 and Mutaf-Yıldız et al., 2020, for reviews). Some studies show that HME is positively and significantly related to students' fourth grade mathematics performance (e.g., Ellis et al., 2023). However, the association between the HME and students' mathematics achievement has mostly been studied in the context of the U.S. and Canada (Hornburg et al., 2021). To our knowledge, only Ellis et al. (2023) explored this association across a larger set of countries; they found a small and significant correlation between HME and mathematics achievement in Chile. Thus, we further explored this association and assessed whether the HME helps explain mathematics variation within and between schools.

Children are exposed to different home learning environments and therefore have different exposure to early mathematics skills. Evidence suggests children who experience a sensitive and cognitively stimulating home environment are more likely to have school success and less likely to experience academic difficulties throughout the schooling years than children who do not experience a cognitively stimulating home environment (Tamis-LeMonda & Rodriguez, 2009). Indeed, a recently developed conceptual process model suggests parental educational attainment is the more powerful predictor of children's academic achievement (Davis-Kean et al., 2021). Thus, we included parents' educational level as a predictor variable in our analyses.

Chilean Context

The Chilean education system is one of the most segregated in the world. Among the Organisation for Economic Co-operation and Development (OECD) countries, Chile has the lowest level of student socioeconomic status (SES) variation within schools but has high levels of status variation between schools (OECD, 2016). School segregation is related to mathematics achievement in Chile, in that students from low-SES schools systematically perform worse in mathematics than students from high-SES schools (Mizala & Torche, 2012; Ramírez, 2006). School segregation is observed, for example, in school resources and teacher qualifications (Mizala & Torche, 2012). Differences in children's mathematics performance might be explained by their schooling experiences. Thus, we explored the variation in students' mathematics performance between and within schools by including school characteristics, such as resources and percentage of socioeconomically disadvantaged students.

In addition to school segregation, Chile has present a consistent gender gap, such that boys perform significantly better than girls in mathematics (Mullis et al., 2020). This gender gap is evident in both national and international standardized tests. Indeed, Chile has one of the largest gender gaps among the OECD countries (Espinoza & Taut, 2020). Different explanations have been proposed for these differences, including mathematics–gender stereotypes, self-concept, and teacher-child interactions (Espinoza & Taut, 2020). Because gender gaps are present in Chilean classrooms, we include student gender as a predictor variable in this study.

This Study

This study used a large and representative database (TIMSS) to understand fourth grade students' mathematics performance in Chile and its variability within and between schools through a multilevel analysis. We hypothesized that parents' reports of their children's early mathematics skills before starting first grade predict mathematics performance in fourth grade. Other student characteristics, such as gender and their parents' educational level, were included in our analyses given the importance of these variables in the Chilean context. Consistent with prior studies (e.g., Espinoza & Taut, 2020; Susperreguy et al., 2020), we expected these predictors would be associated with students' mathematics performance in fourth grade. Because parents play an important role in fostering children's early mathematics skills (i.e., before first grade), we explored whether the HME predicts later mathematics skills (i.e., in fourth grade). Given that Chile has a significantly segregated educational system, we also looked at the association between students' mathematics skills in fourth grade and school characteristics, such as the school's resources for mathematics instruction and its percentage of socioeconomically disadvantaged students.

The main contribution of this study is to understand students' mathematics performance by simultaneously considering variables at student and school levels in a country that is consistently low performing in mathematics and has a highly segregated educational system. Specifically, we investigated the following research questions:

1. Does students' mathematics performance in fourth grade vary across schools?
2. To what extent are students' early mathematics skills before first grade, gender, and parents' highest educational level associated with students' mathematics performance in fourth grade? Do these associations vary across schools?
3. To what extent is the home mathematics environment associated with students' mathematics performance in fourth grade?
4. To what extent do the associations between student characteristics and mathematics performance in fourth grade differ by school characteristics (i.e., a school's mathematics resources and its proportion of socioeconomically disadvantaged students)?

Method

Data Source

This study used data from TIMSS 2019. TIMSS is an international assessment that has been administered by the International Association for the Evaluation of Educational Achievement every 4 years since 1995. TIMSS assesses trends in mathematics and science abilities in the fourth and eighth grades in 64 countries. It also collects information about student and family backgrounds, home context, teacher and school characteristics, and curricula (Mullis & Martin, 2013). One primary purpose of TIMSS is to provide information so countries can make evidence-based decisions related to mathematics and science to improve their educational system. We used the public version of TIMSS 2019 for Chile. This was the optimal database for this study because it includes not only students' mathematics outcomes in fourth grade but also parents' reports of their children's mathematics skills before starting first grade, characteristics of the HME, and demographic information about the families and the schools.

Sample

TIMSS uses a two-stage sample design with a random selection of schools as the first stage and a forward selection of student samples at each school as the second stage (Mullis & Martin, 2013). Elementary schools in Chile serve students from kindergarten through eighth grade. A total of 169 elementary schools and 6,322 students in Chile participated in TIMSS 2019 and are included in this study. Students' mean age was 10.07 (*SD* = 0.50); 49.6% were girls.

Measures

Outcome Variable

Later Mathematics Skills — Students' mathematics skills in fourth grade were measured in three domains: numeracy, geometry and measurement, and data display (Foy et al., 2019). TIMSS uses an item response theory (IRT) scaling approach to provide plausible values of students' mathematics achievement. Students answered between 20 and 28 items; some items were multiple choice (worth one point), and others were constructed response items (worth up to two points; Foy et al., 2019). The TIMSS scale for later mathematics skills was used and the Cronbach's alpha for this sample was .97.

Level 1 Variables: Student Characteristics

Early Mathematics Skills Reported by Parents — Early numeracy skill is a Level 1 predictor variable. TIMSS 2019 included the Parent's Perception of Early Numeracy scale (Mullis & Martin, 2013) to measure children's early mathematics skills before beginning first grade. Students were scored based on their parents' reports of how well they could do different mathematics tasks before first grade. Parent ratings of their children's skills have been used across different cognitive and behavioral domains. For example, Lin et al. (2021) found that parental rating of child numeracy skills predicts direct assessment of child numeracy skills (Lin et al., 2021). TIMSS created a scale using five ordinal items that asked the parents whether the child could do the following activities: (a) count by himself/herself, (b) recognize the written numbers, (c) write the numbers, (d) do simple addition, and (e) do simple subtraction. The first three items had four categories (1 = not at all, 2 = up to 10, 3 = up to 20, and 4 = up to 100 or higher). The last two items were binaries (1 = yes, 2 = no; Foy et al., 2019). TIMSS applied IRT to report a scaled score with a minimum value of 4.79 and a maximum value of 12.89 (M = 9.85, SD = 1.80). The Cronbach's alpha of this scale for the Chilean sample was .79.

Home Mathematics Environment — TIMSS 2019 included questions about household routines and parent–child activities before children began first grade. This scale was used to measure the HME as a predictor variable at Level 1. The scale variable was provided by TIMSS based on seven ordinal items using a 3-point scale (often, sometimes, never or almost never), which asked the parents: "Before your child began primary/elementary school, how often did you or someone else in your home do the following activities with the child?" (Foy et al., 2019). The included items were: (a) sing counting songs, (b) play with number toys, (c) count different things, (d) play games involving shapes, (e) play with building blocks or construction toys, (f) play board or card games, and (g) write numbers (Foy et al., 2019). We used the scale score reported by TIMSS. The Cronbach's alpha for the Chilean sample was .78.

Demographics — Because Chile has a gender gap in mathematics, we included children's gender (0 = boys, 1 = girls), which was asked on the student questionnaire. Additionally, because Chile has a segregated educational system and the HME relates to parents' educational level, we included parents' education level as a Level 1 predictor (1 = did not go to school, 2 = some primary, 3 = lower secondary, 4 = upper secondary, 5 = postsecondary but not university, 6 = university or higher).

Level 2 Variables: School Characteristics

School Mathematics Resources — Three items on the principal's questionnaire asked about school resources for mathematics instruction. The three items had the same description and asked, "How much is your school's capacity to provide instruction affected by a shortage or in shortage of the following? Resources for mathematics instruction." The first item focused on library resources relevant to teach mathematics; the second item focused on supplies such as calculators to teach mathematics; and the third item focused on materials or objects to teach mathematics and help students understand, for example, the concepts of quantities (Foy et al., 2019). We used the scale score reported by TIMSS. The Cronbach's alpha for the Chilean sample is .81.

Socioeconomic Disadvantage — School principals were asked to report the percentage of socioeconomically disadvantaged students in the school. They were asked: "Approximately what percentage of students in your school have the following background? Come from economically disadvantaged homes" on a 4-point scale (1 = 0 to 10%, 2 = 11 to 25%, 3 = 26 to 50%, 4 = more than 50%).

Analytical Procedure

Given that students were nested within 169 schools, we used multilevel modeling analyses with two levels, which is the correct model when observations are not independent (Finch et al., 2019). All analyzes were conducted in STATA/SE Version 17 (StataCorp, 2021). We included the student and school weight at each level in the estimation of the models (i.e., the total student weight –"town"-and the school weight –"schwag"). A multiple imputation procedure (eight imputations) was used to handle missing data. This technique provides a more accurate estimation of the standard errors (Newman, 2014).

We used a bottom-up building model approach to address our research questions. First, we ran an unconditional model (Model 1) with students' mathematics achievement in fourth grade as the outcome to calculate the intraclass correlation (ICC) and explore the amount of variance between schools to answer our first research question. Then, we ran a first conditional model (Model 2), adding student characteristics (parents' report of early mathematics skills before first grade, gender, and parents' highest education), and tested for statistical significance and variation across schools to answer our second research questions. Next, we ran a second conditional model (Model 3), adding the HME, to answer our third research question. Finally, we ran a full conditional model (Model 4), in which we included school characteristics (mathematics resources and proportion of economic disadvantage students) to answer our fourth research question. We tested the practical significance of the intercept and slopes between the full conditional and the conditional models. To evaluate model fit, we compared the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) between all the models. Lower AIC and BIC indicate a better fitting model for the data (Burnham et al., 2011).

Results

Preliminary Analyses

Before conducting the multilevel models, we checked some statistical assumptions with residual plots. As shown in Figure 1, the residuals for students' fourth-grade mathematics achievement were normally distributed. Figure 2 shows variation in students' mathematics performance across 10 schools as an example of the 169 schools that were included.

Figure 1

Residuals of Students' Mathematics Performance

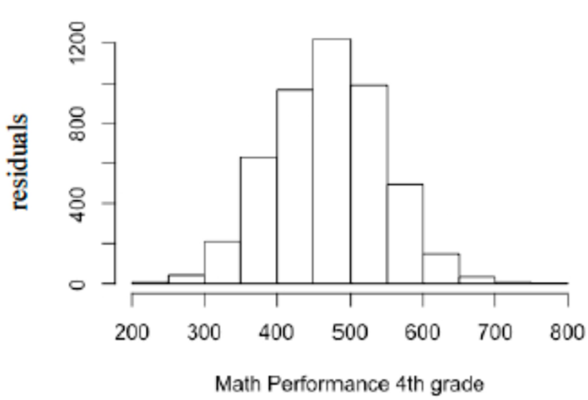
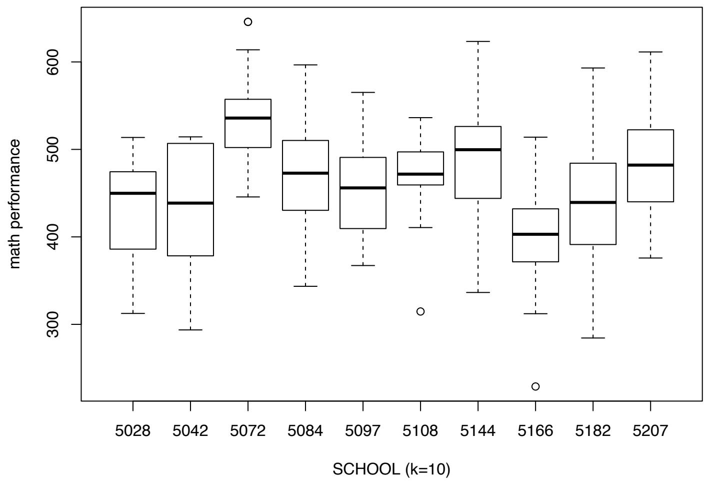


Figure 2

Variation in Mathematics Scores by Schools



The descriptive statistics for each variable are presented in Table 1 and 2. Correlations between our main continuous variables are as follows: parent's report of early mathematics skills before first grade was significantly correlated with later mathematics skills in fourth grade (r = .24). The HME was significantly correlated with both early mathematics skills (r = .20) and later mathematics skills (r = .20). Finally, school mathematics resources was significantly correlated with later mathematics skills (r = .19), early mathematics skills (r = .07), and HME (r = .07).

Table 1

Correlations Among Variables

Variable	1	2	3	4	5	6
1. Later mathematics skills						
2. Early mathematics skills	.230***					
3. Home math environment	.188***	.191***				
4. School resources	.183***	.073***	.074***			
5. Gender	-.073***	-.028***	-.001	.023***		
6. Parents Education	.392***	.056***	.159***	.168***	-.023***	
7. Disadvantage	-.452***	-.080***	-.109***	-.140***	.016***	-.507***

***p < .001.

Multilevel Analyses

In a multilevel model, some regression parameters may be allowed to vary across Level 2 units (and on higher levels, too, if present). For the TIMSS' data, students (Level 1 units) are grouped within schools (Level 2 units). We may expect that students attending different schools will have, on average, different levels of mathematics achievement. Within the multilevel model, this variation is modeled by estimating the overall mean achievement and the variability of these school averages with respect to the overall mean. These two aspects are reported, respectively, by the *fixed* intercept and the *random* variance of the intercept. Similarly, whenever another relation in the model is allowed to vary across schools, it is reported via one average fixed effect and one random variability of that effect among schools.

Table 2

Descriptive Statistics

Variable	%	*M (SD)*	Min.	Max.	Skewness	Kurtosis	Missing %
Student-level variables							
Gender							
Girl	49.62						
Boy	49.72						
Parents' education level							
Less than lower secondary or no school	2.14						
Lower secondary	6.72						
Upper secondary	32.81						
Postsecondary but not university	21.32						
University or higher	28.58						
Not applicable	0.41						
Early mathematics skills		9.76 (1.81)	4.74	13.05	1.81	0.14	0.99
Home math environment		10.18 (2.05)	2.62	15.33	0.28	3.61	1.00
School-level variables							
Economic disadvantage							
0 to 10%	17.95						
11 to 25%	7.56						
26 to 50%	10.90						
More than 50%	57.17						
School resources		10.75 (2.32)	2.27	15.77	0.16	3.36	0.59
Outcome Variable							
Later mathematics skills		453.40 (76.75)	194.80	727.70	-0.04	2.80	0.00

Note. Later mathematics skills = mathematics performance in fourth grade; Early mathematics skills = before first grade, as reported by parents; School resources = instruction affected by a shortage.

Variance of Students' Mathematics Achievement Across Schools

Table 3 shows the results of the fitted multilevel models. To address our first research question and examine how much students' mathematics achievement in fourth grade varied across schools, we ran an unconditional model (Model 1). We observed the variance within and between schools. This is an important step in evaluating whether a nested model is necessary to understand the variance in students' mathematics achievement (Snijders & Bosker, 2012). The ICCs showed that schools explain 29% of the variance of mathematics achievement among students. Overall, students' mathematics achievement in fourth grade was 430.33, significantly different from 0. Thus, because the variance between schools was demonstrated, subsequent analyses included Level 1 and Level 2 components.

Conditional Models

Our next research question examined the associations between student characteristics and mathematics outcomes in fourth grade and explored its variation between schools. Thus, Level 1 predictors (gender, parents' report of students' early mathematics skills before first grade, and parents' highest education) were included in the first conditional model (Model 2). This model shows that all student characteristics significantly predicted mathematics achievement in fourth grade. Girls scored 7.02 points lower in mathematics in fourth grade than boys ($p < .01$). The association between parents' highest education and students' mathematics performance in fourth grade was positive, meaning students whose parents had a higher level of education performed 10.27 points better in mathematics than students whose parents had a lower level of education ($p < .001$). Lastly, higher reported mathematics skills before first grade were associated with higher (B = 7.55) mathematics achievement in fourth grade ($p < .001$). Those three predictors helped explain the mean variation in students' mathematics achievement. Table 4 shows that the inclusion of student characteristics explained 49% of the variance of mathematics achievement at the school level and that 16% of the variance in mathematics achievement was explained by gender, parents' education, and early mathematics skills. Of the remaining variance, 20% was explained by the schools.

Table 3

Multilevel Models Predicting Students' Mathematics Performance

	Model 1 – Null Model (*n* = 6,322)		Model 2 (*n* = 6,322)		Model 3 (*n* = 6,322)		Model 4 (*n* = 6,322)	
Variable	**B (*SE*)**	**β (*SE*)**	**B (*SE*)**	**β (*SE*)**	**B (*SE*)**	**β (*SE*)**	**B (*SE*)**	**β (*SE*)**
Fixed effects								
Student characteristics (First Level)								
Gender (Female)			-7.02** (2.27)	-0.09** (0.03)	-7.05** (2.28)	-0.09** (0.03)	-6.83** (2.32)	-0.09** (0.03)
Parents. Education			10.27*** (1.35)	0.13*** (0.02)	9.51*** (1.35)	0.12*** (0.02)	8.93*** (1.40)	0.11*** (0.02)
Early Math			7.55*** (0.74)	0.17*** (0.02)	6.99*** (0.70)	0.17*** (0.02)	6.87 *** (0.69)	0.16*** (0.02)
HME					2.63*** (0.75)	0.08*** (0.02)	2.68** (0.75)	0.07** (0.02)
School level (Second level)								
School Resources							2.07 * (1.23)	0.06* (0.04)
School Disadvantage							-13.19*** (2.65)	-0.17*** (0.04)
Intercept	430.33*** (3.47)	-0.30 (0.46)	325.85*** (9.20)	-0.70 (0.07)	307.40*** (11.46)	-0.66*** (0.07)	336.18*** (17.29)	-0.01 (0.17)
Random effects								
Level-1 (student) residual (var)	3831.80 (123.66)	0.65 (0.02)	3209.31 (112.29)	0.59 (0.02)	3487.44 (116.23)	0.58 (0.02)	3512.83 (110.21)	0.59 (0.02)
Level-2 (school) intercept (var)	1589.54 (189.55)	0.27 (0.03)	812.53 (195.66)	0.14 (0.03)	591.35 (192.22)	0.14 (0.03)	333.10 (299.79)	0.07 (0.05)
Gender (*SD*)			12.07 (2.70)	0.15 (0.04)	12.21 (2.72)	0.17 (0.04)	12.67 (2.65)	0.17 (0.03)
Parents (*SD*)			5.46 (1.08)	0.07 (0.01)	5.23 (1.02)	0.07 (0.01)	4.74 (1.01)	0.06 (0.01)
HME (*SD*)					1.74 (0.41)	0.10 (0.02)		
School Disadvantage (*SD*)							3.85 (2.40)	0.05 (0.03)

Note. Gender = percentage of female students; Parents education = parents' highest educational level; Early math = students' early mathematics performance before first grade as reported by parents; HME = home mathematics environment; School resources = instruction is affected by the shortage of school math resources; School disadvantage = percentage of students in disadvantaged conditions; var = variance; *SD* = standard deviation.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

We ran a third model to address our third research question, exploring whether the HME was associated with students' mathematics outcomes in fourth grade. As shown in Table 3, Model 3, the HME was found to be positively and statistically significantly associated with students' mathematics performance in fourth grade. The more parents engaged with their children in mathematics activities in the home before first grade, the better the children's performance in mathematics in fourth grade. Students' mathematics performance increased by 2.63 points ($p < .001$). In this model, gender, early mathematics skills, and parents' education were still significantly associated with students' mathematics performance in fourth grade. The residuals at the school level, but not at the student level, decrease after including HME in the model (see Table 3). With these variables in the model, the schools explained 14% of the variance of mathematics achievement and 9% of the variance in mathematics achievement at the student level (see Table 4).

Full Conditional Model

Our final research question examined whether the association between student characteristics and students' mathematics performance in fourth grade differed by school characteristics. Therefore, Model 4 included all the previous Level 1 predictors as well as predictors at Level 2, which were school mathematics resources and students' socioeconomic disadvantage (see Table 3). All the student-level variables (gender, parents' education, parents' report of early mathematics skills, and HME) were still statistically significantly associated with students' mathematics achievement in fourth grade. The associations between achievement and the Level 2 predictors (schools' percentage of socioeconomically disadvantaged students and schools' instruction affected by the shortage of mathematics resources) were significant. The association between schools' percentage of socioeconomically disadvantaged students and achievement was negative, meaning that students in a school with fewer disadvantaged students performed better in mathematics in fourth grade than students in a school with more disadvantaged students (B = -13.19, p < .01). The variable school mathematics resources was also found to be positive and significantly associated with students' mathematics performance in fourth grade (B = 2.07, p < .01). These variables explained 79% of the variance of students' mathematics performance at the school level and 8% of the variance in mathematics performance at the student level (see Table 4).

Table 4

ICC, PRE, and Fit Measures of the Multilevel Models

Variable	Model 1 (Null)	Model 2	Model 3	Model 4
ICC and PRE measures				
ICC School	0.29	0.20	0.14	0.09
ICC student	0.71	0.80	0.86	0.91
PRE school		0.49	0.63	0.79
PRE student		0.16	0.09	0.08
Fit Measures				
Pseudo-deviance	2006294.00	1992712.20	1989476.80	1989886.00
df		8	10	12
AIC		1992728	1991012	1989910
BIC		1992782	1991080	1989991

Note. ICC = intraclass correlation coefficient; PRE = proportion reduction in error.

Across all models, we included random slope variability of the student characteristics within schools. The variation in the effects of gender, parents' education, HME, and school disadvantage was large and varied significantly across schools. Table 3 shows that after controlling for gender, parents' education, and early mathematics skills, the addition of HME in Model 3 explained 63% (PRE = 0.63) of the between-school variance in mathematics performance, increasing it by 14% at the school level. At the student level, however, HME did not help explain much of the variance within schools. This finding indicates that in Chile, the HME is highly related to variance between schools (see Table 4).

After controlling for the four student-level variables, the inclusion of school-level variables in Model 4 (percentage of students at a disadvantage and school mathematics resources) explained 79% (PRE = 0.79) of the between-school variance in math performance, increasing it by 16%. Therefore, school variables contribute to the variance in mathematics performance at the school level.

To identify the best approximation among the set of models under consideration, the models' fits were evaluated by comparing the AIC and BIC indexes presented in Table 4. The AIC and BIC of the second conditional (Model 3) were slightly smaller than those of the first conditional (Model 2). The AIC and BIC of the full model (Model 4) were even smaller, suggesting the best fit to the data is a full model including student and school characteristics.

Discussion

This study used a large, representative dataset to examine how student and school characteristics in Chile related to students' mathematics performance in fourth grade. We also analyzed variance between schools. Previous studies have analyzed these associations separately, but we use a multilevel model to account for those factors together. It was interesting to examine these predictors in Chile due to the large differences between students and schools. Chile not only tends to underperform in mathematics compared to the TIMSS average fourth grade score, but it also has a very segregated educational system and a large gender gap (OECD, 2016). By including variables at different levels (student and school), this study makes an important contribution to the literature. It shows how student and school characteristics help explain variation between schools and how each characteristic relates to students' mathematics performance. This is crucial given the value that mathematics skills have in predicting later academic outcomes and the importance of these skills to thriving beyond the school context.

Regarding student characteristics, the estimated between-school variation of gender in association with mathematics performance in fourth grade is significant, ranging between 12.07 and 12.67 across the models. These results suggest there is a large and significant variation between girls and boys regarding mathematics skills. As fixed effects, we found that female students underperformed in mathematics in fourth grade compared to male students in all the models, which illustrates the pervasive gap between girls and boys in mathematics performance in Chile. This finding aligns with previous research showing a meaningful and statistically significant gender gap in mathematics skills (Wang & Degol, 2017). Espinoza and Taut (2020) found that Chile has one of the largest gender gaps among OECD countries. Future research should examine whether this gender gap starts before elementary school and explore instructional factors that might help explain the difference in mathematics performance between schools based on student gender.

Consistent with our hypothesis, parents' reports of early mathematics skills before first grade were positively and significantly related to children's later mathematics skills in fourth grade. Early mathematics abilities have been found to be a significant predictor of later academic outcomes (e.g., Duncan et al., 2007). Specifically in mathematics, longitudinal studies have found that the development of early mathematics skills is associated with higher mathematics achievement later on; for example, Chu et al. (2018) found that preschoolers' higher understanding of quantitative knowledge and cardinality is related to higher sophisticated mathematical strategies in first grade. In this same direction, Cahoon et al. (2021) found that preschoolers with low numeracy skills have a lower rate of growth than their peers. Those slow rates of mathematical growth may have negative implications for later academic outcomes (Jordan et al., 2006). Given the importance of parental support of children's early mathematics skills, we explored the association between the HME and students' mathematics performance in fourth grade. We found HME significantly predicts students' mathematics skills, as supported by literature (e.g., Ellis et al., 2023; see Daucourt et al., 2021 and Mutaf-Yıldız et al., 2020, for reviews). Thus, the frequency of parent–child interaction at home in relation to mathematics is essential to consider when exploring students' mathematics performance.

Our evidence suggests that Chilean children who experienced more mathematics interactions with their parents at home performed better in mathematics in fourth grade. As Tamis-LeMonda and Rodriguez (2009) held, more cognitively stimulating home environments help foster children's academic experiences. However, a cognitively stimulating home environment is associated with parents' educational levels. Susperreguy et al. (2020) found that a higher frequency of mathematics activities interaction in the home was related to a higher level of parental education. We found Chilean parents' highest educational level to be significantly related to students' mathematics skills in fourth grade: the higher the parents' educational level, the better the student performed in mathematics. In this study, the estimated between-school variation in the association of Chilean parents' education with mathematics performance is large, ranging between 4.74 and 5.46 standard deviations across the models. Parents' educational level is often used as a proxy variable to assess socioeconomic level (Hoff & Laursen, 2019), which is of particular significance in a country like Chile, where the segregation of the educational system is mostly based on families' socioeconomic status.

It is important to highlight that the HME explained more variance at the school level than at the student level. The residuals at the school level decreased after including the HME variable in the model, showing that differences in average mathematics performance between schools are greatly affected by the home environment. This means that there are Chilean schools with high levels of mathematical engagement in the home environment and others with very low mathematical engagement. We found a significant variance that affects students' mathematics performance by the school. This might be explained by the high socioeconomic segregation of the Chilean educational system. This finding could have only been found by using a multilevel model that takes into account students nested within schools allowing us to explore the role of the HME in explaining mathematics performance at both student and school level.

We also found that school characteristics helped explain the variation in students' mathematics performance between schools. The school characteristics (school mathematics resources and percentage of socioeconomically disadvantaged students) were significantly related to students' mathematics skills in fourth grade. Our results show that students performed better in mathematics in schools that had a lower percentage of socioeconomically disadvantaged students, which aligns with research showing a difference in student performance based on a school's socioeconomic level (Mizala & Torche, 2012; Ramírez, 2006). We also found that students performed better in schools that had a lower shortage of mathematics resources.

This study shows that student and school characteristics are essential to explaining students' mathematics performance in Chile. Aligning with bioecological theories of development, the home and school contexts are critical environments for fostering children's skills (Bronfenbrenner & Morris, 2007). We show that school disadvantage is the most important factor predicting children's later mathematics performance, followed by parents' reports of their children's early mathematics skills and parent education. Thus, understanding the role of family and school characteristics in the mathematics learning process is important to consider when developing interventional studies and promoting public policies in education. For example, interventional studies focusing on improving students' mathematics skills might benefit from including the home environment, caregiver-child interactions and activities related to math, as a context to fostering mathematical abilities. At the policy level, it would be beneficial to increase, for example, support in early mathematics skills given that it is one of the highest predictors for latter mathematics outcomes. More work needs to be done at different levels, in school and home contexts, to bridge the gap in students' mathematics achievement.

Limitations and Future Directions

Even though this study makes an essential contribution to the literature by using a nationally representative dataset to demonstrate the significant and extensive variation between schools in terms of students' mathematics performance, it has some limitations. The use of the HME measure has two possible limitations: the accuracy of the report and possible biases in parents' reports. Given that parents responded to the HME items retrospectively, the accuracy of their responses could have affected the final score of the measure. TIMSS also assesses parents' reports of their children's early mathematics skills before first grade by using retrospective reports from parents. However, previous studies have used concurrent and retrospective survey reports (see Daucourt et al., 2021, for a review). Using a self-response survey could lead parents to overestimate the frequency of parent–child interaction because of social desirability bias (Holtgraves, 2004). Future studies should incorporate observational measures to complement self-report surveys of the HME. Additionally, we specifically focused on mathematics skills and did not differentiate it in subdomains (e.g., numeracy, geometry, measurement). Future research could further assess the variation of students' mathematics performance by subdomains.

Conclusion

The study findings extend the literature about the variation of students' mathematics performance between schools in Chile, showing not only gaps between schools but also the importance of other factors, such as gender and the HME, in helping explain variation in students' mathematics performance. Using a nationally representative dataset, we found that student and school characteristics predict later mathematics performance in fourth grade. These results suggest the need to support the home environment, female students, and schools with more socioeconomically disadvantaged students to properly foster students' mathematics skills. Given that one of the primary purposes of TIMSS is to provide information so countries can make evidence-based decisions related to mathematics, we highlight the importance of considering contextual factors, such as the HME, when considering policies and interventions to promote students' mathematics learning process.

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Supplementary Materials: Supplementary materials, including detailed statistical outputs, code, and additional figures, are available upon request from the corresponding author, Jimena Cosso, at jcosso@umd.edu

Data Availability: The data analyzed in this study are publicly available from the Trends in International Mathematics and Science Study (TIMSS) database.

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