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Low SES and High Mathematics Achievement: A Two-Level Analysis of the Paradox in Six Asian Education Systems

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Abstract

Although the impact of family socioeconomic status (SES) on student academic achievement has received much attention in the western literature, studies focusing on the Asian education systems were limited. Guided by Bourdieu's capital theory and the success frame notion proposed by Lee and Zhou, this study examined whether a paradoxical relationship between family SES and the mathematics achievement of students exists across six Asian education systems. Results from a two-level hierarchical linear modeling of PISA 2012 data revealed a positive and significant linear association between family SES and student mathematics achievement in all six Asian education systems as well as a negative and significant quadratic relationship in two of the six education systems. The study provides important understanding about the role of family SES in shaping the academic performances of students in these Asian education systems, especially those from the most socioeconomically privileged families.

Keywords: International comparison, Mathematics learning, Mathematics achievement, Family socioeconomic status, Capital

1. Introduction

The effect of family socioeconomic status (SES) on students' achievement has been well investigated in the western literature. It is generally agreed that students with a higher family SES achieve better than those with a lower SES and family SES background accounts for a major amount of variance in explaining the difference in students' academic performance (e.g., Coleman et al., 1966; Sirin, 2005, White, 1982). Along this line of research, some researchers have found that such relationship between family SES and students' academic achievement does not necessarily apply to a certain group of students such as Asian American students (Kasinitz et al., 2009; Zhou & Bankston, 1998). Instead of being hindered by low family SES, Asian American students quite often achieve much higher than what is predicted by their family SES alone, which seems to be a paradox.

The existing studies provided some information about the relationships between family SES and student mathematics achievement in East Asia. However, these studies were often limited to one particular education system and did not examine such relationship across the major high-achieving Asian education systems (e.g., Liu & Lu, 2008; Zhao, Valcke, Desoete, & Verhaeghe, 2012). Therefore, whether or not such a paradox holds true in East Asian education systems, especially in the subject of mathematics learning, still remains to be explored. A better understanding of the mechanism involved in the paradox may help to shed light on ways of closing the achievement gap that exists between students of higher and lower SES groups in the developed as well as less developed education systems so that the equity issue in education can be more sufficiently addressed.

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Accordingly, this study aims to investigate the relationship between family SES and the mathematics achievement of students in six Asian education systems. Drawing on the international data from the latest wave of Program for International Student Assessment (PISA) 2012, this study examines what types of relationships between family SES and student mathematics achievement exist among the six Asian education systems (Hong Kong, Japan, Korea, Singapore, Shanghai, and Taipei) and whether there are any variations in these relationships among the six education systems.

2. Theoretical Framework

The theoretical framework of the study is informed by the "Capital" theory (Bourdieu, 1986), especially its social, economic capital dimensions, and the notion of "Success Frame" proposed by Lee and Zhou (2014). Bourdieu argued that capitals can be converted to other forms and the functions of social and economic capital make sure the reproduction of social structure and elite status become possible (Bourdieu, 1986). Based on the capital theory, it is assumed that students from families of better social and economic capitals can be supported more sufficiently compared with those students who are from families with less capital. Thus, the resources of affluent families can naturally transform into better academic achievement of their children while those from socially and economically less privileged families would be predestined to remain in their status due to less support of family capitals.

Although the capital theory explains the direct association between family social and economic resources and student academic achievement, it fails to illuminate the paradoxical phenomenon that lower family SES status does not necessarily lead to lower academic achievement, which exists among many Asian American students. A most recent attempt to provide an alternative explanation about such a paradox is the Success Frame notion by Lee and Zhou (2014) based on their analyses of the Immigrants and Intergenerational Mobility in Metropolitan Los Angeles (IIMMLA) survey data and interviews with 1.5- and second-generation Chinese, Vietnamese, and Mexicans participants.

In their study, Lee and Zhou found that, regardless of their family SES, 1.5 and second generation Chinese and Vietnamese share a very similar frame for defining academic success: getting straight A's in school, graduating from elite universities, and then entering prestigious professions like medicine and law after obtaining an advanced degree. This differs from the success model of the Mexican immigrants who often set graduating from high school or local community college as their goal. The notion of success frame overcomes the shortcoming of the capital theory by taking into consideration the contextual factors outside the family to provide a persuasive explanation for the paradoxical phenomenon that Asian children from families of low SES and low parental educational level would manage to achieve high academic outcomes in the end. These contextual factors that contribute to their success include ethnic resources such as Sunday school and local yellow book that has information about the local school ranking and course offering. With the highest possible standards for framing success and ethnic resources, those socioeconomically disadvantaged students could move upwards academically and thus in social status, breaking the cycle set by the traditional capital theory models (Bourdieu, 1986).

With the capital theory and the notion of success frame as a theoretical guide, this study intends to provide further empirical evidence to examine their specific assumptions and to investigate whether such a paradox exists in the high-achieving East Asian education systems.

3. Methodology

3.1. Data Source

The data for six Asian education systems from PISA 2012 was used as the data source of the study due to several considerations. First, PISA 2012 includes nationally representative samples for the 15-year olds obtained from a two-stage stratified sampling scheme for each of the six systems and results from using such samples have better generalizability to inform policy makers and practitioners (Kastberg et al., 2012; OECD, 2013). Second, compared with other international datasets such as TIMSS, PISA dataset provides much richer information about students' family background surveyed from both parent and the students, thus allowing better construction of family SES background to be used for the research questions of the current study (Martin & Mullis, 2012; OECD, 2012a, 2012b). Third, PISA 2012 contains a student achievement measure that can be linked to their family background information, which makes the examination of the relationship between family SES and student achievement possible (OECD, 2013).

Lastly, each wave of PISA data alternates its focus on one of the three subject areas, i.e., reading, mathematics, and science; PISA 2012 was conducted with an emphasis on mathematics, which meets the needs of the research questions of this study (Kastberg et al., 2012).

3.2. Data Analysis

In order to answer the research question and identify the relationship between family SES and students' mathematics achievements in the six education systems, we used hierarchical linear modeling with statistical package HLM 7.01 for the data analysis considering the hierarchical structure of PISA 2012 data (students nested within schools) (Raudenbush & Bryk, 2002; Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2005).

We used the SES indicator provided in PISA 2012 as the independent variable. This indicator, named economic, social and cultural status (ESCS), was created on the basis of the factor scores for the first component from a principal component analysis of two survey items and one composite variable. The two survey items are "highest occupational status of parents" and "highest educational level of parents" in years of education while the composite variable named "home possessions" is derived from all items on the indices of wealth, home educational resources, and cultural possessions (Kastberg et al., 2012).

The 15-year olds' mathematics literacy score was used as the dependent variable for the analysis. The mathematics assessment items in PISA 2012 measured the 15-year olds' ability to solve mathematical problems in real life situations (Kastberg et al., 2012). Students' mathematics achievement measure in PISA 2012 was represented by five plausible values (i.e., pv1math to pv5math) created on the basis of Item Response Theory and each of the five values has an average score of 500 and standard deviation of 100 across all participating economies (OECD, 2013). Theoretically, each plausible variable should be regressed on predictors separately given the same sample data and the results of five individual analyses need be aggregated for final parameter estimates and corresponding standard errors (OECD, 2009). The analysis of five plausible variables can be easily implemented in HLM software and the final aggregated parameter estimates and corresponding standard errors can be derived from the HLM outputs.

To achieve a better estimation of the relationship between family SES and students' mathematics achievement, we used several background control variables. At the student level, student gender and age were controlled; and at the school level, school type (public vs. private) and school location (rural vs. urban) were used as background control variables. Moreover, we imposed sampling weights with student level final weight (W_FSTUWT) at Level 1 and with school level final weight (W_FSCHWT) at Level 2 in HLM to avoid biased parameter estimates due to unequal probabilities of sampling and non-response in PISA (OECD, 2009). Last, we applied group mean centering to all predictors in Level 1 in order to obtain a pure estimate of Level-1 regression coefficients (especially for slope of ESCS and $ESCS^2$) and a more accurate estimate of slope variances (Enders & Tofighi, 2007). After group mean centering was applied, a zero point of ESCS meant student's ESCS was equal to the average ESCS of the student's corresponding school.

For each education system, we specified two models for HLM analyses. Model 1 was an unconditional model without any predictors, while in model 2 we included ESCS, $ESCS^2$, and the covariates from both levels. We included $ESCS^2$ in order to investigate whether there was a quadratic relationship between students' ESCS and their mathematics achievement. Two models are presented as follows.

Model 1. This model is used to investigate the percentage of total variance in students' mathematics achievement existing between schools (Raudenbush & Bryk, 2002).

Level 1:

$$Y_{ij} = \beta_{0j} + r_{ij}, r_{ij} \sim \text{independently } N(0, \sigma^2) \quad (1)$$

Level 2:

$$\beta_{oj} = \gamma_{00} + u_{0j}, u_{0j} \sim \text{independently } N(0, \tau_{00}) \quad (2)$$

In the Level 1 equation, Y_{ij} represents the observed scores of mathematics achievement of *i*th student within *j*th school. Because there is no predictor variable in this model, the intercept β_{0j} indicates the estimated group mean scores (i.e., averaged mathematics achievement scores) of *j*th schools. Moreover, r_{ij} indicates the difference between the *i*th student's score and the mean score of student's corresponding school (residual), which is assumed to be independent from each other and normally distributed with mean equal to zero and variance equal to σ^2, a random effect known as unconditional within-group variance.

In the Level 2 equation, γ_{00} is the estimated grand mean (the mean of school mean scores), which is a fixed effect, while u_{0j} indicates the difference between *j*th school's mean score and grand mean. Additionally, each u_{0j} is assumed to be independent from the others and normally distributed with mean equal to zero and variance equal to τ_{00}, where τ_{00} is a random effect known as unconditional between-group variance.

The sum of two random effects, σ^2 and τ_{00}, is the total variance of observed scores. The intraclass correlation (ICC) is the ratio between τ_{00} and total variance (Hox, 2010; Leeuw & Meijer, 2008; Luke, 2004; Raudenbush & Bryk, 2002):

$$\mathrm{ICC} = \tau_{00} / (\tau_{00} + \sigma^2). \quad (3)$$

The ICC derived by an unconditional model is also called unconditional ICC. The magnitude of ICC can be explained as the percentage of total variance in mathematics achievement that can be accounted for by school level variation.

Model 2. We further estimated the slopes of ESCS and ESCS^2 controlling for student gender, age, school type and location. Moreover, the random effects were fully estimated without any constrains.

Level 1:

$$Y_{ij} = \beta_{0j} + \beta_{1j}(Female_{ij}) + \beta_{2j}(Age_{ij}) + \beta_{3j}(ESCS_{ij}) + \beta_{4j}(ESCS^2{}_{ij}) + r_{ij} \sim \textit{independently } N(0, \sigma^2) \quad (4)$$

Level 2:

$$\beta_{oj} = \gamma_{00} + \gamma_{01}(Public_j) + \gamma_{02}(City_j) + \gamma_{03}(Town_j) + u_{0j}, u_{0j} \sim \textit{independently } N(0, \tau_{00}) \quad (5)$$

$$\beta_{1j} = \gamma_{10} + u_{1j}, u_{1j} \sim \textit{independently } N(0, \tau_{11}) \quad (6)$$

$$\beta_{2j} = \gamma_{20} + u_{2j}, u_{2j} \sim \textit{independently } N(0, \tau_{22}) \quad (7)$$

$$\beta_{3j} = \gamma_{30} + u_{3j}, u_{3j} \sim \textit{independently } N(0, \tau_{33}) \quad (8)$$

$$\beta_{4j} = \gamma_{40} + u_{4j}, u_{4j} \sim \textit{independently } N(0, \tau_{44}) \quad (9)$$

In the Level 1 equation, β_{1j}, β_{2j}, β_{3j}, and β_{4j} denote the predictive power (slopes) of Level 1 predictors for each school; β_{0j} denotes the intercepts for each school; and r_{ij} is the residual for each individual. As mentioned previously, group mean centering is applied to all Level 1 predictors. In the Level 2 equation, all β_s are treated as outcomes. We were most interested in parameters γ_{30} and γ_{40}, which were the point estimate of slopes for ESCS and ESCS^2, respectively (Raudenbush & Bryk, 2002). Moreover, u_{0j}~u_{4j} are assumed to be independent from r_{ij} and normally distributed with mean equal to zero and variance equal to τ_{00}, τ_{11}, τ_{22}, τ_{33}, and τ_{44}, correspondingly.

It should be noted that τ_{33}, and τ_{44} are random effects that capture the variation of slopes of ESCS and ESCS^2 across schools, respectively.

4. Results

We presented the weighted descriptive statistics of the outcomes and predictors in Table 1. The results of Model 1 were presented in Table 2. The estimated grand mean mathematics achievement score for the six educational systems ranged from 508.79 to 598.59. Japan had the highest level of ICC (54.93%), followed by Hong Kong (44.75%), Taipei (40.03%), Shanghai (36.71%), Singapore (35.60%), and Korea (34.02%). Apparently, Japan was the only educational system that had more than half of the variation in mathematics achievement score existing between schools, which indicates that the mathematics achievement mean scores of schools were more widely dispersed in Japan compared to the other educational systems.

Table 1: *Weighted descriptive statistics of selected outcomes and predictors*

	Hong Kong	Japan	Singapore	Korea	Shanghai	Taipei
Level 1						
Sample Size	4,670	6,351	5,330	5,033	5,177	6,046
Pv1math	561.42(95.87)	536.66(93.55)	574.24(105.91)	554.27(98.65)	611.66(100.43)	559.58(115.72)
Pv2math	560.62(96.49)	536.28(93.36)	574.27(105.29)	553.27(98.94)	613.07(100.91)	559.07(115.88)
Pv3math	560.84(96.35)	536.39(93.69)	574.47(106.12)	553.66(98.91)	612.96(100.79)	560.80(115.75)
Pv4math	561.60(96.45)	536.22(93.64)	574.55(105.26)	553.47(99.42)	613.00(101.44)	560.54(115.53)
Pv5math	561.73(96.44)	536.49(93.41)	574.07(106.06)	554.16(99.51)	612.69(101.37)	560.57(115.22)
Female	0.46(0.50)	0.47(0.50)	0.49(0.50)	0.47(0.50)	0.51(0.50)	0.51(0.50)
Age	15.74(0.29)	15.79(0.29)	15.78(0.29)	15.71(0.29)	15.76(0.29)	15.74(0.30)
ESCS	-0.79(0.97)	-0.07(0.71)	-0.26(0.91)	0.01(0.74)	-0.36(0.96)	-0.40(0.84)
Level 2						
Sample Size	148	191	172	156	155	163
School type – Public	6.01%	74.98%	81.24%	64.42%	91.59%	80.00%
School type – Private (reference group)	93.99%	25.02%	12.04%	35.58%	8.41%	20.00%
School type – N/A	0.00%	0.00%	6.72%	0.00%	0.00%	0.00%
School Location – Village	0.00%	0.00%	0.00%	5.48%	0.00%	13.05%
School Location – Town	0.00%	36.26%	0.00%	13.13%	0.00%	47.15%
School Location – City (reference group) [a]	100.00%	63.74%	93.29%	81.39%	100.00%	39.80%
School Location – N/A	0.00%	0.00%	6.71%	0.00%	0.00%	0.00%

Note. [a] The predictor School Location of Hong Kong, Shanghai, and Singapore had no variability and was not included in the analyses. Descriptive statistics of variables in student level (Level 1) were weighted by variable W_FSTUWT, while variables in school level (Level 2) were weighted by variable W_FSCHWT. The mean and standard deviation for continuous variables and percentage for categorical variables were presented here.

We presented the results of Model 2 in Table 3. The results indicated that the linear relationship between ESCS and mathematics achievement was positive and significant with different levels of strengths that ranged from 4.35 to 28.78 in the samples of the six education systems, holding all other predictors constant. More specifically, the slope of ESCS was relatively smaller in Japan (4.35) and Hong Kong (4.46). However, a comparatively larger effect of ESCS was identified in the samples of Shanghai (10.21), Singapore (20.63) and Korea (28.29), and the largest effect of ESCS (28.78) was found in the sample of Taipei.

Additionally, Korea had the largest variation of ESCS impact across schools (τ_{33} = 639.68). Using the equation ESCS$\pm$1.96*$\sqrt{\tau_{33}}$ (Raudenbush & Bryk, 2002), we further estimated the range of ESCS slope (-21.28, 77.86) for 95% of the schools in Korea. The range of ESCS slope suggested the influence of ESCS might be dramatically large or negative for some Korea schools. Moreover, among the six education systems, we found a significant and negative quadratic relationship between ESCS and student mathematics achievement in the samples of Shanghai and Taipei. As shown in Table 3, the slopes of ESCS^2 for Shanghai and Taipei were 4.58 (p < .05) and -8.50 (p < .01) respectively. Considering a possible range of ESCS held by students, we presented the association between ESCS and mathematics achievement score in Figure 1 for Shanghai and Taipei students in public schools located in city area, holding all other predictors constant. The pattern of ESCS-mathematics achievement score relationship can be applied to students in different school type or school locations as well. Since ESCS was a group-centered predictor, a zero point of ESCS meant students' ESCS was equal to that the average ESCS of the student's corresponding school.

Table 2: *Results of Model 1*

	Hong Kong	Japan	Singapore	Korea	Shanghai	Taipei
Fixed Effects						
Intercept	546.61*** (7.62)	508.79*** (7.33)	565.82*** (5.73)	532.11*** (7.71)	598.59*** (5.66)	527.06*** (12.73)
Random Effects						
τ_{00}	4499.055***	5147.28***	3761.32***	3539.32***	3539.72***	6012.83***
σ^2	5554.045	4223.68	6803.32	6865.59	6103.58	9006.55
ICC	44.75%	54.93%	35.60%	34.02%	36.71%	40.03%

Note. ***p < .001

Table 3: *Results of Model 2*

	Hong Kong	Japan	Singapore	Korea	Shanghai	Taipei
Fixed Effects						
Intercept	546.60*** (7.93)	526.63*** (9.08)	543.76*** (13.38)	545.64*** (10.00)	639.24*** (13.26)	531.00*** (15.03)
Public	41.21* (18.14)	-9.47 (15.32)	26.473* (13.20)	13.79 (12.59)	-41.17* (14.15)	57.51** (16.80)
Village	-	-	-	-47.13 (30.08)	-	165.58*** (19.68)
Town	-	-27.16 (15.39)	-	-23.82 (17.43)	-	-49.45*** (11.98)
Female	-20.19*** (3.65)	-13.80*** (3.62)	-0.45 (2.93)	-7.94 (5.89)	-13.03*** (2.80)	1.28 (4.59)
Age	9.64* (4.83)	7.68* (3.57)	-0.79 (4.27)	-24.84** (9.37)	-25.40** (7.98)	28.10** (10.45)
ESCS	4.46** (1.53)	4.35* (2.03)	20.63*** (2.04)	28.29*** (5.74)	10.21*** (2.14)	28.78*** (3.29)
ESCS^2	-2.12 (1.71)	0.81 (2.47)	-1.87 (1.61)	1.61 (3.38)	-4.58* (1.96)	-8.50** (2.84)
Random Effects						
τ_{00}	4224.50***	4974.40***	3955.01***	3580.68***	3401.241***	3076.18***
τ_{11} (Female)	181.80	255.56***	143.79	121.23	77.739	299.47*
τ_{22} (Age)	436.85	94.93	178.67	845.44***	1992.304***	610.09*
τ_{33} (ESCS)	29.71	72.52*	125.36**	639.68***	169.869***	156.29**
τ_{44} (ESCS^2)	55.33*	105.37*	56.21	51.49***	75.739*	115.71*
σ^2	5278.50	3990.67	6314.80	6263.14	5595.180	8106.59

Note. *p < .05; **p < .01; ***p < .001

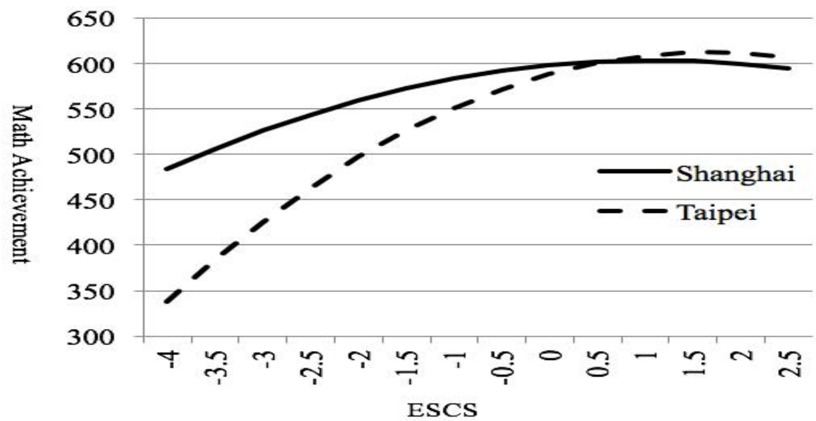

Figure 1. Students' predicted mathematics achievement scores as a function of ESCS for Shanghai and Taipei.

We found there was an inverted-U relationship between ESCS and mathematics achievement for both educational systems. More specifically, ESCS was an influential factor on mathematics achievement score especially for students whose ESCS status was lower than the school's average. However, the impact of ESCS shrank if the ESCS score increased. In Shanghai, the peak mathematics achievement score was found when students' ESCS was above school's average by 1.0 to 1.5 points. Interestingly, we found for Shanghai students whose ESCS was above the school average by 2.5 points, their predicted mathematics achievement score (595.01) was lower than that of students whose ESCS was equal to the school's average (598.07). Similarly, in Taipei, the peak mathematics achievement score was spotted when students' ESCS was above the school average by 1.5 to 2.0 points. The predicted mathematics achievement score of Taipei students whose ESCS was above school's average by 2.5 points was 607.30, which was lower than that of students whose ESCS was above school's average by 1.0 point (608.78).

5. Discussion and Conclusion

Using two different conceptualizations of the role of family SES, this study found similarities as well as variations regarding the role of parental SES in shaping students' mathematics performance in these six Asian education systems. The current study provides empirical evidence to challenge the popular assumption about the impact of family SES on 15-year old Asian students' mathematics achievement, and offers insight into the paradoxical result regarding the role of SES in some Asian education systems.

First, this study revealed a positive and significant linear association between family ESCS and students' mathematics achievement in all six Asian education systems. Confirming the importance of parental SES in affecting student mathematics achievement, this result is consistent with the prior finding of a multitude of studies (e.g., Coleman et al., 1966; Sirin, 2005, White, 1982).

Secondly, results of the study indicate that, in addition to the positive and significant linear correlation found in all six Asian education systems, a negative and significant quadratic correlation was also found between family ESCS and students' mathematics achievement in Shanghai and Taipei. Though both found a quadratic non-linear association, the current study's result about the Shanghai sample is in conflict with the positive quadratic association that Zhao et al. (2012) found about the Chinese elementary school students in their study. The different results might be attributed to difference in the age and school type of the samples in the two studies. Based on their analysis of 10,959 elementary school students from both rural and urban schools, Zhao et al. (2012) found that the Chinese elementary school students from the higher and lower family SES actually outperformed those from the average family SES background. However, the current study used a sample of 15-year olds who were all from urban high schools in Shanghai and found that students from the highest SES did not achieve the corresponding performance level predicted by their SES background. Such age and school type factors might have led to the differences in the results of the two studies.

Additionally, this study contributes importantly to the understanding of the theoretical assumptions about the relationship between family SES and student academic achievement. First, it challenges the assumption of the capital theory (Bourdieu, 1986). As is indicated by the results of the study, the capital theory does not always hold true in explaining the relationship between family SES and student mathematics performance for all six Asian education systems. While it can be used to explain the association between family SES and student mathematics performance in four of the six Asian education systems, it is unable to explain why the mathematics performance of students that are the most socioeconomically advantaged in Shanghai and Taipei tend to lose the competitive edge that family SES affords to them. Instead of being predicted by their family SES to perform at a higher level, these students actually underperform. While the success frame proposed by Lee and Zhou (2014) can be used to explain the paradox found in Zhao et al.'s study (2012), it seems incapable of shedding light on the paradox exposed in the current study. It is therefore necessary for researchers to come up with new theoretical assumptions in order to elucidate the nature and causes of this contradiction.

Overall, results from the study challenged the assumptions of the capital theory (Bourdieu, 1986) and the notion of success frame proposed by Lee and Zhou (2014), while at the same time provided further empirical evidence regarding the existence of the high-SES-low-performance paradox. To conclude, this study adds to the existing literature and helps refine our understanding of the role family SES plays in shaping students' mathematics performance in some Asian education systems. It inspires more studies along this line of research to better understand the impact of family socioeconomic background on the mathematics achievement of students, especially those from the most privileged backgrounds, and thus better address the educational equity issue in these education systems as well as in others around the world.

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