



# A multilevel analysis of Japanese middle school student and school socioeconomic status influence on mathematics achievement

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**Abstract** The author examined the simultaneous influence of Japanese middle school student and school socioeconomic status (SES) on student math achievement with two-level multilevel analysis models by utilizing the Trends in International Mathematics and Science Study (TIMSS) Japan data sets. The theoretical framework used in this study was Bronfenbrenner's bioecological theory (Bronfenbrenner and Morris 1998). The data sets contained 4,856 students from 146 public and private middle schools. The results indicated that at the student level, different aspects of student SES (i.e., number of books, the possession of computers, paternal, and maternal educational achievements) were positively related to Japanese student math achievement. At the school level, two aspects of school SES (i.e., less populated schools and economically disadvantaged schools) were negatively related to Japanese student math achievement. None of the cross-level interactions were significant, but the random effect for the computer slope was significant. Although this study found both student and school SES effects on student achievement, the proportional reduction of prediction error explained by both student and school SES were was small, meaning the residual variances at student and school levels did not capture the majority of variance explained by math achievement. The implications of theoretical framework and educational policy are discussed.

**Keywords** Japan · Socioeconomic status · Multilevel analysis · TIMSS · Middle schools · Math achievement

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## 1 Introduction

Socioeconomic status (SES) creates inequality and unfairness, and the studies of SES have been flourishing globally. For example, researchers found SES effects on students and/or schools (e.g., Beese and Liang 2010; Greenwald, Hedges, and Laine 1996; Liu, Wu, and Zumbo 2006; Liu, Van Damme, Gielen, and Van Den Noortgate 2015; Nonoyama-Tarumi 2008; Rumberger and Palardy 2005; Van Ewijk and Slegers 2010). The main SES issue is uncontrollable family background, such as parental income and education, which influences students' achievement greatly (Sudo 2009). Especially, low SES has detrimental life effects on developing basic learning skills, learning competencies, parenting and child development, motivation, aspirations, expectations, and study hours (Hoffman 2003; Kariya 2004; Kariya 2010; Kariya and Rosenbaum 2003; Orr 2003).

Studies on SES effects in Japan were not actively conducted until the 2000s for some political and social reasons (Sudo 2009). The main social reason was the classifications within the Japanese society. Japan did not have obvious social class or ethnic issues unlike the US and other European countries (Sudo 2009). Thus, differential academic achievement did not receive enough attention for researchers to conduct research in SES areas (Mimizuka 2007). The major political issue was that the government rarely had conducted any systematic research on examining student academic achievement for 40 years until 2002 (Mimizuka 2007). The Japanese Teachers' Association was strongly against the Ministry of Education conducting nationwide tests because they were afraid that student test scores would be used against teachers in evaluations and students for their future employment opportunities. Eventually, the Japanese Supreme Court supported the union and ordered the stoppage of nation-wide tests in the 1960s for the next 40 years (Kariya 2006). Because of this, researchers were unable to obtain any public data to study (Sudo 2009).

Due to the considerable delay of SES studies, there are insufficient numbers of studies especially using multilevel analysis with Japanese middle school students. Students attending the same schools tend to share similar educational expectations (Heck, Thomas, and Tabata 2014), and single-level analyses of students or schools ignore the simultaneous effects of students and schools. In other words, without a hierarchical nature of student and school-level analysis, the combined impacts of student and school SES on academic achievement are not clear. Multilevel analysis would be appropriate to examine simultaneous effects of Japanese middle school student and school SES on math achievement.

### 1.1 Research questions

The purpose of this study was to investigate how Japanese student socioeconomic characteristics (i.e., home resources, parental education, supplemental education) and school socioeconomic characteristics (i.e., location of schools and schools with economically disadvantaged students) simultaneously affected student math achievement by utilizing multilevel analysis models with a large secondary data sets.

To be more specific, the author proposed three research questions, which were guided by Bronfenbrenner's bioecological theory (Bronfenbrenner and Morris 1998). Bronfenbrenner's bioecological theory was used as a theoretical framework in the joint

contexts of Japanese middle schools, parental influence, and Japanese student math achievement. Since this theoretical framework has been widely used in SES studies (e.g., Tudge, Otero, Hogan, and Etz 2003), it may be helpful in explaining how reciprocal interactions between Japanese middle school students and their parents influence student academic achievement. The details of the theoretical framework are discussed in the literature review. The research questions in relation to the theoretical framework and multilevel analysis are as follows:

1. Do Japanese eighth graders' levels of math achievement influenced by their SES vary across schools?

Two home microsystems as contexts (i.e., home possessions and parental education), person (i.e., Japanese eighth graders), proximal processes (i.e., studying math as supplemental education), and developmental outcome (i.e., math performance) were used to assess the influence of student SES within the bioecological theory.

2. Do Japanese student levels of math achievement influenced by their SES and school SES vary across schools after controlling for their individual SES?

There were two aspects of school microsystems (i.e., the location of schools and the economically disadvantaged school status), two of home microsystems (i.e., home possessions and parental education), and person (Japanese eighth graders), proximal processes (studying math as supplemental education), and outcome development (math achievement) in the bioecological theory.

3. Does Japanese middle school SES moderate Japanese student SES and math achievement relationships?

This research question involved developmental outcome (math achievement), person (Japanese eighth graders), school microsystems (the location of schools and the economically disadvantaged school status), home microsystem (home resources and parental education), and proximal processes (studying math as supplemental education) as elements in the bioecological model.

The author herein explains student characteristics first and then school characteristics after the theoretical framework in the literature review.

## 2 Literature review

### 2.1 Theoretical framework

Urie Bronfenbrenner's bioecological theory (Bronfenbrenner and Morris 1998) as a theoretical framework takes into account the joint influence of middle schools, parent(s), and Japanese students' characteristics on their academic achievement in the context of SES. Lerner (2005) explained that the bioecological theory consists of four interrelated components of developmental processes (process); an individual's biological, cognitive, emotional, and behavioral characteristics (person); an individual's nested context (context); and the relationship with time (time). The author chose this theory because the bioecological model explains joint functions of developing individuals and their various surrounding contexts in relation to their developmental outcomes (Tudge et al. 2009).

### 2.1.1 Process

The first core of this theory is process. In order for an individual to achieve progressive development, proximal processes must be increasingly complex and prolonged and must occur on a fairly regular basis (Bronfenbrenner and Morris 2006). Proximal processes are not limited to an interaction between people but also include an interaction between objects and symbols (Bronfenbrenner and Morris 1998; Bronfenbrenner and Morris 2006), such as studying math as supplemental education after school in this study.

### 2.1.2 Person

There are three types of biological and genetic personal characteristics: dispositions, resources, and demand characteristics that contribute to processes throughout the life course development in order to affect content, form, power, and direction of the proximal processes (Bronfenbrenner and Morris 2006). Disposition characteristics are temperament, motivation, and persistence, which set proximal processes in motion and continue to maintain proximal processes (Bronfenbrenner and Morris 1998; Tudge et al. 2009). Resource characteristics are an individual's ability, experience, knowledge, and skills, which are necessary for effective proximal processes (Tudge et al. 2009). Demand characteristics are demographic information, such as age, gender, and ethnicity, which immediately create stimulus to another individual (Tudge et al. 2009). In this study, personal characteristics were Japanese eighth graders attending middle schools.

### 2.1.3 Context

Context or environment has four interrelated systems: microsystem, mesosystem, exosystem, and macrosystem, which influence proximal processes (Tudge et al. 2009). Microsystem refers to the relation between a developing individual and the immediate environment, such as home or school (Bronfenbrenner 1994). Mesosystem consists of two or more microsystems and involves at least two settings, including a developing individual with, as an example, home-school relations (Bronfenbrenner 1994; Bronfenbrenner 1999). Exosystem also includes two or more environments; however, it indirectly involves a developing person and one of the environments, which does not contain the developing person (Bronfenbrenner 1994). Macrosystem refers to social structure or institutional patterns of culture, such as customs and beliefs (Bronfenbrenner 1994; Bronfenbrenner and Morris 2006). This can be used for comparing different cultural values or comparing high and low-SES families.

In this study, two microsystems (student and school SES) were used.

### 2.1.4 Time

Time also influences proximal processes. Time has three different aspects: micro-, meso-, and macro-. Microtime is created when ongoing proximal processes discontinue and continue (Bronfenbrenner and Morris 1998). Mesotime is the time interval of the period of proximal processes, such as weeks and days (Bronfenbrenner and Morris 1998; Bronfenbrenner and Morris 2006). Macrotime marks changes over one's life course, such as a change in the employment status and place of residence

(Bronfenbrenner 1994). In this study, time component was not used because it was unavailable in the data sets.

## 2.2 Student characteristics

### 2.2.1 Home possessions

The inclusion of home possessions is a recent trend in indicators (Sirin 2005). Despite the recent popularity, some researchers disagreed with home resources as an SES indicator (Duncan and Brooks-Gunn 1997; Magnuson and Duncan 2006). For example, Magnuson and Duncan (2006) argued that home resources might not be appropriate SES indicators because they reflect parents' preferences more than their social and economic status. However, researchers (e.g., Hojo 2011; Lee and Croninger 1994; Liu et al. 2006; Yoshino 2012) found that different home possessions were positively related to student scores in Japan and in international studies. The inclusion of home possession variables such as computers is a more up-to-date indicator that should be incorporated into studies to be relevant to the current middle school students' situation. Thus, the effect of home possessions should be examined in relation to student math achievement in this study.

### 2.2.2 Shadow education

Shadow education (supplemental education) is ubiquitous, especially in East Asia, such as in Japan, South Korea, Taiwan, and Hong Kong (Bray and Kwok 2003). The trend in shadow education is not limited to Asia anymore. Shadow education is not only common in East Asia, but also in other parts of the world, such as the USA (Buchmann, Condron, and Roscigno 2010; Yi 2013), Europe (Bray and Kwok 2003), and Turkey (Tomul and Savasci 2012). One possible reason for the well-established shadow education in East Asian countries may be the influence of Confucian beliefs (Bray and Kwok 2003). First and foremost, shadow education is seen in a diverse range of societies regardless of one's ethnic background, SES, and type of government (Bray and Kwok 2003). Second, educational attainment is increasingly important in the competitive world economy. Most people need good college degrees to qualify for good jobs and advancement (Yi 2013). This means that shadow education exacerbates social inequalities (Bray and Kwok 2003) between those who can afford and those who cannot afford higher education.

Japan has established a long history in shadow education since the 1930s (Sato 2005). Shadow education is called *juku* in Japan, and it is a big business. The prestigious *juku*, which offer high school entrance exam preparation classes, charge about \$460 for middle school students per month (Tsumura 2005). Kariya (2008) concluded that students who do not use *juku* are underprivileged.

In previous studies, the effect of shadow education is mixed in Japan and in international studies. Both positive and negative results of shadow education have been found. Some scholars (Kariya 2008; Liu et al. 2006; Tomul and Savasci 2012; Yamamoto and Brinton 2010) found that shadow education was positively related to student achievement in Japan and other countries. However, shadow education was also negatively related to student achievement in Korea and Taiwan (Liu et al. 2006).

This negative effect may be caused by student depression, academic dishonesty by students and parents, disassociation from peers, and institutional cheating (Yi 2013). Yamamoto and Brinton (2010) criticized the inclusion of shadow education in many empirical studies at the high school level or higher as problematic and recommended that shadow education be used in order to assess early academic achievement as well as in later educational attainment. Shadow education is deeply rooted in the Japanese educational system; hence, the investigation of shadow education is important at the middle school level.

### 2.2.3 Parental education

Entwisle and Astone (1994) stated that parents with higher education degrees could help their children's work, encourage them to pursue higher education, and develop their language abilities. In addition, educated parents can afford a higher quality of educational services, whereas under-educated parents have limited access to such higher quality of educational services (Schiller, Khmelkov, and Wang 2002). Much research showed that parental levels of educational achievement were related to their children's achievement. Both parental educational backgrounds were influential on student achievement in both international and Japan studies (Liu et al. 2006; Kaneko 2004; Marks 2008; Sanchez, Montesinos, and Rodriguez 2013; Tomul and Savasci 2012). On the other hand, Liu et al. (2006) did not find that parental education was related to math achievement in Korea, Singapore, and Hong Kong. In summary, the effect of parental education-student achievement should be investigated.

## 2.3 School characteristics

### 2.3.1 Schools with economically disadvantaged students

Socioeconomic school compositional effects influence beyond students' family background and academic outcome (Palardy 2013). Many scholars have found the influence of economically disadvantaged schools in relation to student academic achievement in Japan and other countries (e.g., Beese and Liang 2010; Condon et al. 2012; Hojo 2011; Liu et al. 2006; Liu, Van Damme, Gielen, and Van Den Noortgate 2015; National Institute for Educational Policy Research (NIER) 2009a; Van Ewijk and Slegers 2010). Students from economically affluent schools outperform those from economically disadvantaged schools.

Another issue is that school SES residual variance accounted for by Japanese student math achievement in multilevel analysis is not clear in the Se re-investigated with secondary data sets.

### 2.3.2 School locations

One study showed school compositions such as school locations were associated with student math achievement in PISA data sets (Liu, Van Damme, Gielen, and Van Den Noortgate 2015). Location of schools seems to matter; however, the results are incongruent in Japan and other countries. Some researchers found that students from

urban schools outperformed those from rural areas (Hamano 2009a; Mohammadpour and Ghafar 2014 and others found the opposite results (Hojo 2011; Tayyaba 2010; Thirunarayanan 2004). It seems that these incongruent results are due to the differences between the unique school location characteristics within the countries. For example, Thirunarayanan (2004) explained that urban areas have issues, such as poverty, unemployment, crime, lack of affordable housing, and teacher shortage in the USA. These conditions seem to negatively impact students' performance in urban areas in the USA. Since there are inconsistent findings in Japanese studies, school location should be re-investigated. Especially, more studies on comparisons between urban and other regions are necessary with Japan data sets (Kawaguchi 2011). Location of schools seems to be related to schools' SES, and school SES incorporates a family's SES. Further, there are few jobs available, and family income tends to be lower in rural areas relative to metropolitan areas; thus, location of schools tends to be related to family's income. In summary, the effect of school location on student achievement is far from conclusive; thus, this variable should be re-investigated.

### 3 Methods

The author used scores and various other variables from 4856 randomly selected Japanese eighth graders (male = 2455, female = 2401) from 146 (public and private middle schools) from the Trends in International Mathematics and Science Study (TIMSS) Japan 2003 data. Since the classification of public and private middle school in the data sets was not specified, it was impossible to separate them. Thus, the author focused on the results for public schools only. As public middle schools dominate more than 90% in Japan, the emphasis on public schools would be justifiable. TIMSS 2003 data was chosen because this data had a questionnaire pertaining to shadow education. The NIER (2003) used two-stage stratified probability sampling techniques for selecting schools and individuals in order to meet the TIMSS guidelines for assessing students' educational progress. The International Association for the Evaluation of Educational Achievement (IEA) sets the mean math score at 500 points with a standard deviation of 100 in the previous TIMSS scores. The TIMSS measured two domains of math abilities: cognitive domain (knowing, applying, and reasoning) and content domain (number, algebra, geometry, data, and chance) (NIER 2003).

#### 3.1 Variables

The dependent variable was an individual average of five plausible math test scores, which was used to assess student overall math achievement.

As for independent variables, the five student variables were father and mothers' levels of education (re-coded 0 = junior school, 1 = high school, 2 = vocational school, 3 = university, and 4 = graduate school), the possession of computers (re-coded 0 = no, yes = 1), number of books at home (re-coded 0 = 0–10 books, 1 = 11–25, 2 = 26–100, 3 = 101–200, 4 = more than 200), and the participation of extra math lessons after school (re-coded as 0 = never or almost never, 1 = sometimes, 2 = once or twice a week, 3 = every or almost every day). Extra math lessons represented shadow education in this study. These variables were to measure student SES.

The two school-SES variables were the percentage of schools with economically disadvantaged students (re-coded 0 = 0–10%, 1 = 11–25%, 2 = 26%–50%, 3 = more than 50%) and the type of communities (the author called it location of schools in this study) (re-coded 0 = more than 500,000 people, 1 = 100,001 to 500,000 people, 2 = 50,001 to 100,000 people, 3 = 15,001 to 50,000 people, 4 = 3001 to 15,000 people, and 5 = fewer than 3000 people).

### 3.2 Multilevel analysis

The benefits of a multilevel analysis model are herein explained. First, the analysis takes into consideration Japanese eighth graders nested within middle schools. Treating students as if they were independent of an organization potentially creates analysis bias and ignores the similar educational attitudes shared with others within the groups (Heck et al. 2014). Second, multilevel analysis allows a decomposition of the variations in student math achievement into within-and between-school variance. This enables the identification of substantial differences among schools (Raudenbush and Bryk 2002). Third, multilevel analysis models allow formulating and testing of hypotheses such as cross-level interactions. The cross-level interaction examines how higher-level variables (i.e., school-level) would influence lower-level variables (i.e., student-level) in this study (Raudenbush and Bryk 2002). Because of these statistical advantages, the author designed two-level multilevel analysis models with full maximum likelihood estimation with EM algorithm.

The model for student-level was

$$\begin{aligned} \text{score}_{ij} = & \beta_{0j} + \beta_{1j} * (\text{books}_{ij}) + \beta_{2j} * (\text{computers}_{ij}) + \\ & \beta_{3j} * (\text{maternal education}_{ij}) + \beta_{4j} * (\text{paternal education}_{ij}) + \\ & \beta_{5j} * (\text{extra math lessons}_{ij}) + r_{ij} \end{aligned} \quad (1)$$

where  $\text{score}_{ij}$  is the math achievement for  $i$  student in  $j$  school,  $\beta_{0j}$  is the school mean,  $\beta_{1j}$  is the regression coefficient associated with books for  $j$ th school, and  $r_{ij}$  is the student residual in school  $j$ . At the student-level,  $r_{ij} \sim N(0, \sigma_2)$ .

The model for the school-level was

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (\text{school location}_j) + \gamma_{02} * (\text{disadvantaged school}_j) + \mathcal{U}_{0j} \quad (2)$$

where  $\gamma_{00}$  is the school grand mean,  $\gamma_{01}$  is the regression coefficient associated with school location,  $\gamma_{02}$  is the regression coefficient associated with disadvantaged schools, and  $\mathcal{U}_{0j}$  is the school residual related to the intercept (grand mean).

If the student SES slopes are allowed to vary randomly across schools, possible variance in each slope (e.g., books-math score slope) would be explained by the school-level predictors (i.e., school location and disadvantaged schools).

The variation in random slope is indicated by adding a variance parameter (e.g.,  $u_{1j}$  for the books-math random slope). However, it is likely that most potential randomly varying parameters below are to be fixed at the school level (i.e., where the variance parameters  $u$  are removed). Generally, possible variation in student-level regression



slopes at the school-level is examined using only one random slope at a time as seen below in Eq. 3.

$$\begin{aligned}
 \beta_{1j} &= \gamma_{10} + \gamma_{11} * (\text{school location}_j) + \gamma_{12} * (\text{disadvantaged school}_j) + U_{1j} \\
 \beta_{2j} &= \gamma_{20} + \gamma_{21} * (\text{school location}_j) + \gamma_{22} * (\text{disadvantaged school}_j) + U_{2j} \\
 \beta_{3j} &= \gamma_{30} + \gamma_{31} * (\text{school location}_j) + \gamma_{32} * (\text{disadvantaged school}_j) + U_{3j} \\
 \beta_{4j} &= \gamma_{40} + \gamma_{41} * (\text{school location}_j) + \gamma_{42} * (\text{disadvantaged school}_j) + U_{4j} \\
 \beta_{5j} &= \gamma_{50} + \gamma_{51} * (\text{school location}_j) + \gamma_{52} * (\text{disadvantaged school}_j) + U_{5j}
 \end{aligned}
 \tag{3}$$

where  $\gamma_{10}$  is the student slope (i.e., books-achievement),  $\gamma_{11}$  is the cross-level interaction between school location and books,  $\gamma_{12}$  is the cross-level interaction between disadvantaged schools and books, and  $u_{1j}$  is the school residual related to the book slope. At school-level, the below assumptions are made.

$$\begin{bmatrix} u_{0j} \\ u_{1j} \end{bmatrix} \sim N_2[0, T], \text{ where } T = \begin{bmatrix} t_{00} & t_{01} \\ t_{01} & t_{11} \end{bmatrix}$$

### 3.3 Model comparisons

The purpose of model comparisons is to provide information about the integrity and trustworthiness of models (Ferron, Hogarty, Dedrick, Hess, Niles, and Kromrey 2008). Model selection is an important part of multilevel modeling, and comparing models is necessary to identify the most superior model (McCoach and Black 2008). Since the models in this study were not nested, Akaike information criteria (AIC) was applied. The smaller AIC value is the best model regardless of the number of parameters in the models (Heck et al. 2014).

The author compared the four models. Model 1 was a null model with no predictors. Model 2 included random intercepts with student-level predictors (i.e., research question 1). Model 3 contained random intercepts with both student and school-level predictors (i.e., research question 2). The author created this model to determine

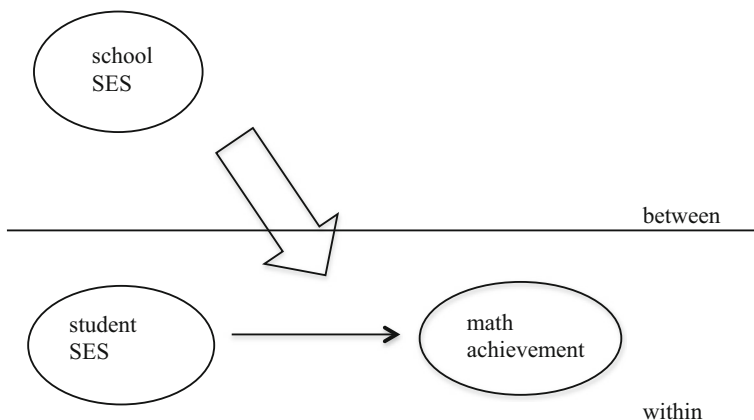


Fig. 1 Proposed final two-level multilevel analysis model

whether random intercept models for student and school SES would vary across schools. Model 4 included both student and school-level predictors with cross-level interactions (i.e., research question 3). The cross-level interactions examined how school location would moderate student SES (i.e., books, computers, extra math lessons, father, and mothers' education) and how disadvantaged schools would moderate student SES in relation to student math achievement. Figure 1 presents the final proposed model (model 4) of the two-level multilevel analysis models.

The proportional reduction of prediction error was calculated to get total variance reduction estimations for levels 1 and 2 rather than parameter specific variance estimates. This is because most of the models were random intercept models. This method is also interpreted as estimating variance explained.

The estimate in proportional reduction of prediction error, like the proportion of variance, explains changes in the amount of residual variance that were produced from one model compared to a comparison model (McCoach and Black 2008).

Before conducting analyses, the author conducted multiple imputation five times in order to deal with missing values, and "I do not know" responses with paternal and maternal education, schools with economically disadvantaged students, and the location of schools based on the variables were missing at random (MAR). Multiple imputation replaces missing values by creating a number of imputed data sets, and each data set contains a different plausible value of the missingness instead of creating one imputed data set for estimating the missing values (Peugh and Enders 2004). This was a necessary procedure since there were missing values and high "I do not know" responses especially in father and mothers' educational backgrounds.

The author applied house weight for students and total school weight for schools to estimate the correct parameter estimates and over-proportionate samples (Thomas and Heck 2001). Regarding centering the variables, the author centered books, extra math, father, and mothers' levels of education as group mean. Since computer variable was dichotomous, it was not centered. The author centered location of school and disadvantaged school as grand mean. Mplus and HLM software for multiple imputation and multilevel analyses were used. The University's Internal Review Board (IRB) approved

**Table 1** Descriptive statistics for level 1 and level 2

Level 1	<i>N</i>	Mean	SD	Skewness	Kurtosis
Variables					
Scores	4785	569.39	76.46	-0.17	0.06
Books	4785	3.02	1.26	0.07	-0.93
Computers	4785	0.82	0.38	-1.66	0.75
Extra math	4785	1.76	0.91	0.65	-1.07
Maternal edu	4785	1.70	1.29	0.24	-0.63
Paternal edu	4785	1.93	1.57	-0.04	-0.96
Level 2					
Variables					
School loc	146	1.30	1.30	0.63	-0.66
Sch disadv	146	0.59	0.59	1.79	3.05

**Table 2** Correlations between the predictors

Variable	Books	Computers	Extra math	Maternal edu	Paternal edu	School loc	Sch disadv
Books	1.00	–	–	–	–	–	–
Computers	0.28	1.00	–	–	–	–	–
Extra math	0.17	0.17	1.00	–	–	–	–
Maternal edu	0.03	0.02	0.07	1.00	–	–	–
Paternal edu	0.25	0.24	0.17	0.07	–	–	–
School loc	0.32	0.24	0.22	0.06	0.55	1.00	–
Sch disadv	–0.11	–0.06	–0.08	–0.06	–0.12	–0.15	1.00

this study as exempt from federal regulations relating to the protection of human research subjects.

## 4 Results

### 4.1 Preliminary results

Table 1 presents descriptive statistics for levels 1 (students) and 2 (schools). These statistics are based on the results of multiple imputation. The final respondents were 4785 Japanese students from 146 Japanese middle schools. Table 2 presents the correlations between the predictors. This procedure examined whether both student and school predictors were highly correlated for a chance of multicollinearity. The result displayed that all correlations were either low or moderate; thus, there were no signs of collinearity. Since results were based on imputed variables,  $p$  values were unavailable in Mplus.

### 4.2 Primary results

Table 3 indicates fixed effects, variance components, variance reduction, and AIC as below. The results of model 1 indicate that intra-coefficient correlation (ICC) was 19% of variance that lay between schools and 81% of variance that lay within schools. This indicates that Japanese students tended to be homogeneous across schools and the difference laid largely within-schools rather than between-schools. This result is reasonable since more than 90% of Japanese middle-school students go to public middle schools in their districts (NIER 2010). The school intercept or school grand mean for all 146 schools was 566.79, indicating that Japanese students scored high grades in math and placed fifth in TIMSS in 2003. The random intercept parameter indicated that the school intercepts varied significantly across schools, meaning that math achievement varied across schools ( $\tau_{00} = 1113.19$ ,  $p < .001$ ). There was also significant variance to be explained at the student level ( $\sigma^2 = 4682.19$ ,  $p < .001$ ). Thus, the next model included student predictors to explain within-student variability.

The findings of model 2 show that computers, paternal education, maternal education, and books were positively related to student math achievement.

**Table 3** Fixed effects, variance components, variance reduction, and AIC for two-level multilevel models

Parameter	Model 1 (baseline)	Model 2 (students)	Model 3 (stud & sch)	Model 4 (interactions)
<b>Fixed Effects</b>				
Intercept	566.79 <b>**</b> (2.95)	560.68 <b>**</b> (3.54)	563.57 <b>**</b> (3.48)	562.67 <b>***</b> (3.92)
Books	–	10.73 <b>**</b> (0.85)	10.73 <b>**</b> (0.85)	–
Computers	–	7.59 <b>**</b> (2.53)	7.44 <b>**</b> (2.52)	–
Extra math	–	–0.23(1.11)	–	–
Maternal edu	–	4.27*(1.54)	4.26*(1.54)	–
Paternal edu	–	12.58 <b>**</b> (1.40)	12.58 <b>**</b> (1.40)	–
School loc	–	–	–8.75 <b>**</b> (1.94)	–5.41(2.75)
Sch disadv	–	–	–14.78 <b>**</b> (5.14)	–12.57(6.94)
Sch loc*books	–	–	–	–0.41(0.64)
Sch dis*books	–	–	–	–1.45(1.62)
Sch loc*comp	–	–	–	–3.82(2.19)
Sch dis*comp	–	–	–	–2.69(5.28)
Sch loc*mat	–	–	–	1.84(1.28)
Sch dis*mat	–	–	–	–0.21(3.10)
Sch loc*pat	–	–	–	–1.13(1.16)
Sch dis*pat	–	–	–	–2.28(2.39)
<b>Variance Components</b>				
Lev1 residual	4682.19 <b>**</b> (68.43)	4161.06 <b>**</b> (64.51)	4160.19 <b>**</b> (64.50)	4074.43 <b>**</b> (63.83)
Lev2 intercept var	1113.19 <b>**</b> (33.36)	1097.54 <b>**</b> (33.13)	936.24 <b>**</b> (30.60)	1262.13 <b>**</b> (35.53)
Book slope var	–	–	–	8.81(2.97)
Comp slope var	–	–	–	349.81*(15.81)
Pat slope var	–	–	–	15.16(3.89)
Mat slope var	–	–	–	16.20(4.02)
Extra slope var	–	–	–	–
<b>Variance Reduction</b>				
Level 1	–	0.10	0.02	N/A
Level 2	–	0.03	0.13	N/A
AIC	54,526.15	53,943.63	53,932.79	53,927.73

Standard errors and SD are in parentheses. Variance reduction was not calculated for the last model since the model was not nested.

\* $p < .05$ , \*\* $p < .001$

The books coefficient (coded 0 as 10 or fewer books to 4 as more than 200 books) therefore suggested that one unit increase in books was related to 10.73 points increase in Japanese student achievement, holding other variables constant. Students who had computers were more advantaged than those who did not have computers. As the computer variable (coded 1 as yes and 0 as no), on average, students who possessed computers were likely to score 7.59 points higher than those who did not have computers, controlling for the influence of other variables. Both father and mothers'

levels of education were significantly related to math achievement. More specifically (i.e., both variables coded middle-school graduates = 0 to having graduate school degrees = 4), a unit increase in mothers' education was related to an average 4.27 point increase in student achievement, holding other variables constant. A unit increase in fathers' education was related to a 12.57 point increase in student math scores, holding other variables constant. Comparing father and mothers' educational influence, fathers' levels of education tended to have stronger influence than mothers'. The extra math lesson variable was not related to student achievement.

The variance component also suggested that there was still variability to be explained between schools ( $\tau_{00} = 1097.54, p < .001$ ). In the next model, school variables were added to explain this variability in addition to student variables.

Based on the non-significant results from this analysis, extra math lesson variable was removed from the next analysis.

The results of AIC indicated that AIC on model 2 was smaller than AIC on model 1. This indicates that adding the student SES predictors (i.e., maternal education, paternal education, books, computers, and extra math) were more useful than having no predictors in model 1.

The findings of model 3 suggest both schools with economically disadvantaged students and less populated schools negatively related to math achievement. More specifically, (coded 0 = less than 10% disadvantaged students to 3 = 50% or more disadvantaged students) on average, a one-unit increase in proportion of disadvantaged students in the schools would result in an average of decrease of 14.78 points in school math scores, holding other variables constant. With regard to school location, (coded 0 = more than 500, 000 people or metropolitan area to 5 = less than 3000 people or rural area) as one population category is decreased in terms of the location of school, on average, Japanese students were likely to decrease 8.75 points in math achievement, holding other variables constant. From this result, it can also be interpreted that students who attended less populated schools (e.g., rural area) were more disadvantaged than those who attend more populated schools (e.g., urban area).

Comparing AIC in model 3 to model 2, AIC was smaller in model 3. This suggests that adding the school SES predictors (i.e., school locations and disadvantaged schools) was useful to the model that did not have any school SES predictors.

The results of model 4 indicate that none of the cross-level interactions were significant, meaning none of the school SES predictors (i.e., school locations and disadvantaged schools) moderated student SES-math achievement relationships. As for random effects, the only significant student-level slope was for having a computer at home. This means that the relationships between the size of the effect for having a computer on math achievement varied from school to school (Heck et al. 2014). In other words, the impact of utilizing a computer in math learning is stronger or weaker in some schools (Raudenbush and Bryk 2002). The student slopes (books, maternal, and paternal education) or the relationships between books-math scores, maternal-math scores, and paternal-math scores were non-significant.

Comparing AIC in model 4 to model 3, AIC was smaller in model 4. This indicates that adding the cross-level interactions of school SES and student SES were more useful to the model than the previous model. Although this model was the best and the

most parsimonious model that describe the phenomena of student and school SES in relation to student math achievement in this study, it should be noted that AIC was not much different between model 4 and model 3.

The proportion of reduction in prediction error at student-level was 10% and at school-level was 13% from these models (see Table 3). This means that most of the variance in math achievement was unexplained.

## 5 Discussion

This study examined Japanese eighth graders and Japanese middle school SES simultaneous influence on student math achievement with TIMSS data sets by utilizing Bronfenbrenner's bioecological theory (Bronfenbrenner and Morris 1998).

### 5.1 Student characteristics

The results of the first research question partially confirmed that Japanese students' level of math achievement, influenced by their SES, varied across schools. Japanese students who had more home possessions (i.e., computers and more books) tended to be more advantaged than those who had few possessions. These findings were consistent with Japanese and international research (Liu et al. 2006; Yoshino 2012).

Both father and mothers' educational backgrounds were positively related to student achievement; especially, the fathers' influence was greater than mothers' influence on Japanese student math scores. This study also found that paternal educational background was more influential than maternal educational background. However, the author did not deny the influence of maternal education. This study's finding was congruent with others' findings (Marks 2008; Tomul and Savasci 2012). In contrast with this study's finding, other research results found that mothers' education was more influential than fathers' (Marks 2008). These inconsistent results imply that the impact of paternal education may be contextual. Marks (2008) found in his cross-national study that paternal education tended to be more influential in math, whereas maternal education had a stronger impact on reading than paternal education.

If the dependent variable were a different subject such as reading, maternal influence could have been stronger than paternal influence in this study.

In contrast to the popular demand for shadow education, extra math lessons variable was unrelated to math achievement. This study found that students who did not utilize shadow education were not underprivileged. This study result was inconsistent with others' findings (Kariya 2008; Liu et al. 2006; Tomul and Savasci 2012; Yamamoto and Brinton 2010). Several reasons may be considered for this result. The participation difference in shadow education in different grades (i.e., eighth vs ninth graders) (Benese Educational Research and Developmental Institute Corporation 2005), geographic locations (i.e., urban vs suburban areas) (Hamano 2009a), and the types of extra math lessons (i.e., remedial vs advanced classes) might have contributed to such findings. In addition, the negative aspects of shadow education, such as student depression and disassociation from peers (Yi 2013) might have diminished the effect of shadow education.

## 5.2 School characteristics

The findings of the second research question confirmed that school locations and disadvantaged Japanese middle schools negatively influenced student math achievement after controlling for the student SES variables. For school locations, Japanese students who go to schools in rural areas compared to those who attend schools in metropolitan areas are disadvantaged. This result is congruent with other findings in Japan and in international studies (Mimizuka 2007; Mohanmmadpour and Ghafar 2014; Tomul and Savasci 2012); however, it is incongruent with others (Hojo 2011; Tayyaba 2010; Thirunarayanan 2004). The reasons for the location differences may be due to individual differences instead of school differences (Shimizu and Sudo 2008). Another reasons may be the existence of more competent private middle schools in urban areas (Mimizuka 2007). In addition, students' high participation in shadow education and more availability for extracurricular social activities in urban areas than in rural areas may favor urban students academically more than rural students (Tomul and Savasci 2012).

With regard to school SES, schools with economically disadvantaged students were negatively related to student math achievement. This is due to the fact that economically disadvantaged schools are made up of students with lower SES backgrounds. One study concluded that the school compositional effect made by student's socioeconomic backgrounds was strong on student math achievement in PISA data (Liu, Van Damme, Gielen, and Van Den Noortgate 2015). This study's result is consistent with previous findings in Japan and in international studies (e.g., Beese and Liang 2010; Condon et al. 2012; Hojo 2011; Liu et al. 2006; NIER 2009a; OECD 2013; Van Ewijk and Slegers 2010) but is inconsistent with Liu et al. (2006). The reason for the inconsistent finding was unclear.

The negative effect of economically disadvantaged schools may be interpreted as that learning environments at high-SES schools create a more favorable environment than at low-SES schools (Palardy 2013). Such favorable conditions are associated highly with school achievement (Liu, Van Damme, Gielen, and Van Den Noortgate 2015; Rumberger and Palardy 2005). To the contrary, students attending low-SES schools are less likely to take advanced math coursework and are more negatively influenced by their peers (Palardy 2013). Thus, Japanese students attending economically affluent schools are given more opportunities than those attending economically disadvantaged schools, which results in their higher math scores.

The findings of research question 3 did not support that the interactions between students and schools SES were related to math achievement. The findings indicated that Japanese school SES neither moderated nor diminished Japanese student SES and math achievement relationships.

There were no comparable studies with which to compare this result since the cross-level interactions were rarely tested in other studies. In order to confirm the interaction effects on student achievement, more studies are needed.

Only the computer slope (i.e., relationship between computer and student math achievement) had a significant variation among schools. This finding implies that some students in some schools tend to use computers more often in their math studies than those in other schools. Middle school students watch YouTube, download free test questions, post questions onsite, and use chat room to ask friends questions (Benesse Educational Research and Developmental Institute 2014). Utilizing computers for

learning math is a trend for students in addition to traditional study approaches. The usage of computers divided students' math learning results.

This study confirmed both student and school SES effects; however, it found a small proportion of variance in prediction error at student and school-levels. This result may be explained in a few ways. First, the stratification of Japanese public middle schools may be one of the reasons. Japanese students are assigned by the local educational administrators to attend nearby public middle schools regardless of their academic achievement. As a result, high variation within schools may result in smaller school SES. Rumberger and Palardy (2005) confirmed that after school differences were removed, there was high variability in student achievement.

Second, the funding sources for Japanese public middle schools may make school SES less effective. Japanese public schools are funded from government, prefectures, and municipal authorities. However, 30% of the funds come from the government and 70% are from prefectures and municipal authorities in Japan (MEXT, 2016). Because of the relatively large financial support from the government, the negative effect of low-school SES may become less severe. This may explain the low-SES school residual variance in this study. In contrast, about 93% of public school funds are from state and local levels and 7% are from the government in the USA. On a local level, these funds are based on property taxes, which creates gaps between economically affluent and economically disadvantaged schools in the USA (Public Broadcasting Service, 2008). These factors may explain why middle school SES effects are smaller in Japan than those in the USA.

## 6 Theoretical implication

This study investigated the three interrelated relationships between home/school contexts, Japanese middle school students, and shadow education. More specifically, there were home microsystems (student SES) and school microsystems (school SES) as context, person (Japanese eighth graders), proximal processes (extra math lessons), and students' developmental outcome (math achievement). Since the proximal process is the core engine of Bronfenbrenner's bioecological theory, several implications related to proximal processes are mainly discussed. This study did not find any significant role of proximal processes as discussed in the literature. Japanese eighth graders did not benefit shadow education as proximal processes in their outcome development. This may be because the nature of proximal processes varies as a function of individuals, contexts, and time (Bronfenbrenner and Morris 1998). Since the frequent and constant participation for extended periods of time in immediate contexts was required for effective proximal processes (Bronfenbrenner and Morris 1998), ninth graders would be more likely to benefit from utilizing proximal processes than eighth graders in order to prepare for high-stakes high school entrance exams.

Proximal processes might have been a different variable, for example, interactions between school teacher and student might have been ideal proximal processes since such interactions occur everyday at school. However, this sort of variable was unavailable in the data sets. Different proximal processes as variables should be reconsidered in future studies.



Another implication is that even though person-symbol interactions (i.e., studying extra math) are part of proximal processes (Bronfenbrenner and Morris 1998; Bronfenbrenner and Morris 2006), these interactions may be weaker as proximal processes, and hence, person-symbol interactions may not be ideal candidates for proximal processes. These interactions may be also more difficult to assess methodologically because reciprocal interactions are hard to detect relative to person-person interactions.

Two contexts of home and school were related to Japanese students' developmental outcomes (i.e., academic achievement). Especially, Japanese students with more educated fathers were more advantaged than those with less educated fathers. The contextual influence of school and family was confirmed in relation to math achievement, but not of proximal processes.

The theory stated that effective proximal processes flourish in stable and predictable family environments, whereas effective processes weaken in unstable and unpredictable family situations (Bronfenbrenner 1995; Bronfenbrenner and Ceci 1994; Bronfenbrenner and Morris 1998). Since the influence of proximal processes was not confirmed in this study, the influence of home and school microsystems as contexts in relation to proximal processes was unable to be confirmed.

It is also noteworthy that even though this study did not incorporate the time component, it may affect this study's finding since one's developmental processes are likely to be affected by historical events (Tudge et al. 2009). Economic distress will likely influence Japanese student performance negatively, especially for low-SES students. Economic hardship is likely to influence student achievement directly, such as reducing participation in shadow education and parental income. Economic hardship is also likely to influence indirectly student academic performance. For example, when parents suffer from economic distress, this may affect their mood. As a result, parents may become more impatient toward their children, and their attitudes may indirectly affect their children's achievement (Bronfenbrenner 1994). On the contrary, economic depression is less likely to affect high-SES Japanese student achievement because they tend to be more financially stable (Bronfenbrenner and Morris 1998).

In summary, although this study did not find any effective role of proximal processes, this may be because proximal processes vary depending on the context, personal characteristics, and time as the literature suggested. In different home and school microsystems and in different grades, proximal processes may be more significant.

## 7 Limitations and future directions

There were three major limitations in this study. First, usage of the secondary data sets presented limitations in the measurements of SES definitions in this study. The author used extra math lessons (i.e., shadow education) and home resources (i.e., computers and books) to measure parental wealth. These parental wealth variables might have inadequately measured only a part of student SES variables. The author used two school variables to assess school SES variables, and they also could have been too limited to measure the variety of school SES indicators. Second, a lack of variety of SES variables in TIMSS data sets may not represent all of the typical SES indicators, such as parental income and occupation. This lack of traditional SES variables might have caused small residual variance at the student-level. Future studies should use more

diverse student SES and school SES variables to explain the majority of residual variance at student-level and school-level in the context of Japanese middle schools. Third, Bronfenbrenner (2005) stated that among the theoretical models, time has a special importance in assessing one's developmental process. This study was able to test three components (i.e., proximal process, person, and contexts), however, was unable to test a time component due to the lack of variables from the data sets.

## 8 An implication for educational policy

An educational policy is suggested for alleviating such negative school impacts on student academic achievement, such as the negative influence of disadvantaged schools and the location of less populated areas. A government research agency found that teaching student math according to differential academic abilities helped low-math achieving students to accomplish better scores (NIER 2009b). Although more studies should be conducted in this area before it becomes a public policy, teaching students according to their academic abilities may help reduce the negative school impacts.

## 9 Conclusion

This study contributed to the scarce SES studies in Japan in the context of Japanese middle-school students with Bronfenbrenner's theoretical framework. This study found that uncontrollable student and school SES contextual factors simultaneously influenced student math achievement in Japan. In order to alleviate unequal SES issues in Japanese society, educational policies, laws, and community support would be helpful. Especially, government support and community involvement will be helpful for meeting the needs of low-SES families in order to reduce the gaps between them and high-SES families and thereby to diminish inequality in education.

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