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수학교육 형평성에 미치는 학교 영향: PISA 2015를 이용한 다수준 분석

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Effects on equity in mathematics education: Multilevel analysis via the PISA 2015

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초록

교육에서 사회경제적 지위에 따른 성취 수준의 차이를 이해하는데 개인배경 뿐만 아니라 학교의 영향력, 그리고 두 요인의 상호작용을 함께 고려하는 것은 중요하다. 이러한 이유로 본 연구는 각 학교에 재학 중인 학생들의 사회경제적 지위의 평균으로 표현되는 학교 수준의 사회경제적 지위를 고려하여, 수학적 소양에서 나타나는 형평성을 분석하는 것을 목적으로 하였다. PISA 2015에 참여한 우리나라 학생 5,548명(168개 학교)과 미국 학생 5,217명(161개 학교)의 자료를 계층적 선형 회귀 분석을 이용해 분석 및 비교하였다. 그 결과, 우리나라의 경우 개인 수준의 사회경제적 지위에 따른 성취 격차보다 학교 수준의 사회경제적 지위에 따른 성취도 차이가 큰 것으로 나타났다. 미국의 경우 대조적으로 개인의 사회경제적 배경이 열악할 때 학교 수준의 사회경제적 지위와 상관없이 기대할 수 있는 수학 성취도 수준이 낮았다. 이러한 결과는 우리나라 학생들의 수학적 성취에 학교 수준의 사회경제적 지위가 추가적인 불평등의 기제로 작용할 수 있음을 시사한다. 국내의 교육현실에서 학교 수준의 사회경제적 지위가 사교육 및 교육과정 선택 등의 이슈와 얽혀있다는 점에서 수학교육에서의 불평등 문제 해결의 실마리를 발견할 수 있을 것으로 기대한다. 또한, 수학 교육자들에게 우리의 문제를 해결하기 위해 단순히 다른 교육 시스템을 모방해서는 안 됨을 상기시킨다.

Abstract

The interaction between student and school levels should be considered to understand and examine equity in education. For this reason, we included the socioeconomic composition of schools to scrutinize the equity related to students' socioeconomic status and mathematical literacy in Korea. We applied the hierarchical linear modeling approach to the Programme for International Student Assessment (PISA) 2015 data for binational comparison between Korea (5,548 students from 168 schools) and the U.S. (5,217 students from 161 schools). The findings show that school-level achievement and the socioeconomic composition of schools cannot be ignored to understand Korean students' achievement gap between high and low socioeconomic status. In addition, U.S. students from low socioeconomic status were likely to have similar mathematics literacy scores. These findings indicated that inequity in Korean mathematics education could be intertwined with the characteristics of Korean students like high demands for supplementary private education and school characteristics like curriculum selection. This research also reminds mathematics educators that people should not simply mimic other education systems to resolve education issues in their own system.

* 주요어 : 형평성, PISA 2015, 학교수준 사회경제적 지위, 수학적 소양
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Ⅰ. Introduction

There are increasing attentions to equity in mathematics education regarding gender, ethnicity, and socioeconomic status (SES). Internationally, the Organization for Economic Co-operation and Development (OECD, 2016a) shows that individuals' socioeconomic backgrounds are positively related to mathematics achievement with different degrees among countries. Locally in Korean education system, studies on the relationships between academic achievement and SES have a long history because supplementary private education (e.g., hagwon in Korea; OECD, 2016a) has been an important issue related to students' academic success (Kim, 2000). Thus, the positive relationships between SES and achievement are not new at all, and educators have attempted to resolve the inequity in education related to SES (Langenkamp & Carbonaro, 2018).

While SES is a characteristic of students' background positively associated to achievement, researchers have also considered the socioeconomic composition of schools, which is an average socioeconomic status of students within a school. The socioeconomic composition of schools has been studied as a significant factor with positive effects on academic achievement because schools is a place where the individual's resources and school resources interact. The socioeconomic composition of schools can be related to tracking, teacher's experiences and professional development, and availability of textbooks or counselors (Baker, 2017; Bidwell & Kasarda, 1980; Brookover et al., 1978; Kalogrides & Loeb, 2013). Students form the low SES family background could have more advantages from schools with the high socioeconomic composition compared to their peers in low-socioeconomic-composition schools. This could be because low SES students could have opportunities to use materials and resources provided by schools, which are not available in their home. The interaction between resources at student and school levels is significant to understand equity in education better.

This idea about the socioeconomic composition of schools can be extended to local communities or school districts considering geography of schools. Because school SES is an average socioeconomic statuses of students in a school, school SES might be a characteristics of not only a school, but also a community where students live. Particularly, residential segregation in the United States exacerbates inequity in schools and makes schools less diverse (Logan, Minca, & Adar, 2012). Poverty has a large but simple composition effect of home and parental background as well as neighborhood situations (Lareau, 2003). With this perspective, it is interesting to examine the equity in education considering the socioeconomic composition of schools because of unique features of Korean education systems. Supplementary private education could be a significant resource that students can access in their community, but not a part of public schools (Byun, Chung, & Baker, 2018).

We expect to examine different patterns in Korean contexts from what prior studies have found with the U.S. contexts because of the following two reasons: First, it is expected that the within-school effects of inequity on students' achievement are minimal because of the efforts of the Korean government to offer similar quality of teaching (e.g., the same standards for teaching certificate for all schools and teacher rotation among schools; National Center on Education and the Economy [NCEE], n.d.). Second, the between-school effects are relatively large when we consider the influence of supplementary private education, which is probably related to the geography of schools (Lee & Yang, 2012). In other words, we hypothesize significant relationships between schools (actually related to geography of schools), but quite homogeneous relationships within schools.

The purpose of this study is to investigate the equity in mathematics education with regards of SES using a multilevel model. We analyzed the Programme for International Student Assessment (PISA) 2015 data of Korean and U.S. students. A rationale to use PISA data is that international comparison studies can provide opportunities to find similarities and differences of the Korean education system to other educational systems as well as articulate the general characteristics of Korean education by analyzing large-scale data. Another rationale s the target population. The TIMSS have examined fourth graders in elementary schools and second graders in middle schools. However, the PISA have focused on the first graders in high schools, which means that we expect to investigate the relationships between socioeconomic status and achievement more clearly since students are more close to the Korean college entrance exam.

We selected the U.S. for comparison with Korea. This selection is grounded on the finding that the U.S. educational system has a huge diverse in schools in terms of ethnicity and SES (OECD, 2016b). For example, the SES composition ranges from -1.65 to 1.13 for the U.S. and from -1.06 to 0.68 for Korea (see Table 2 in the results section). In addition, the Korean and U.S. education systems are distinguishable by supplementary private education and educational policies like standardization of public schools. With these differences between the U.S. and Korea, the comparison can explicitly inform whether our hypothesize is acceptable although an underlying mechanism is out of the scope of this quantitative research, necessitating follow-up studies to articulate it. It should be noted that we mainly focused on better understanding of the Korean educational system via binational comparison. The U.S. have remarkably different policies and system compared to Korea although the U.S. students' average was below the OECD average and the number of students in the low achievement level was increasing in PISA 2015. Thus, because of the differences in the systems, we argued that the U.S. is appropriate for the comparison.

As mentioned before, we recognized the possible influence of school-level socioeconomic status on student achievement from the previous review of literature. Focusing on mathematical literacy, this research is guided by the following questions: (1) what are the relationships between students' socioeconomic status and mathematical literacy examined in the PISA 2015 considering the socioeconomic composition of schools? And (2) what are differences in the relationships among students' socioeconomic status, the socioeconomic composition of schools, and mathematical literacy between Korea and the United States?

Ⅱ. Literature Review

To address our research foci guiding this research, we draw two literature bases - equity in education and the socioeconomic composition of schools. Based on these, we will discuss what are equity in education and the socioeconomic composition of schools. In addition, it is important to address why the socioeconomic composition of schools is important in research on equity in education.

1. Equity in Mathematics Education

It is not new anymore to educators that students from high SES families outperform their peers from low SES families (Lee, 2005). Although we shift our focus from academic achievement to mathematical literacy, the finding is consistent (Morgan, Farkas, Hillemeier, & Maczuga, 2009; Hwang, Choi, Bae, & Shin, 2018). As recognizing academic performance is closely related to one's quality of life (OECD, 2008), equity in education becomes one of recent and critical issues particularly in mathematics education (Boaler, 2002).

Although educators have paid more attentions to equity in education, there have been a variety of the ways to define equity in education. Those ways to characterize equity ineducation depend on where researches put an emphasis in explanation about how inequity occur. The dictionary definition of equity is keeping fairness and justice by eliminating uneven starting points or providing extra measurements to disadvantaged groups of people (American Library Association, 2014). In educational studies, equity is defined as equal access to educational resources and equality in learning outcomes (Lynch, 2000). Furthermore, equity is involved in equal connections between learning experience and family culture, and equal distribution of agency. These definitions help researchers to understand learning mathematics with a socio-cultural perspective. In addition, disadvantaged groups of students could have equal access to education because individual academic success is likely to results in one's higher quality of life (OECD, 2008).

The discussions about equity yield the question how to measure and examine equity quantitatively. The approach provided by the PISA is an answer of that question. The PISA is interested in students' scientific and mathematical literacy as well as equity in mathematics and science education, which means "ensuring that education outcomes are the result of students' abilities, will, and effort, and not the result of their personal circumstances" (OECD, 2016b, p. 39). Thus, the PISA argued that equity in education is closely related to policy efforts, in other words, it is a matter of how to use resources more appropriately and promote social cohesion. To examine equity in education, the PISA conceptualize it through the strength of the relationships between SES and mathematical literacy. Strong correlations between SES and mathematical literacy mean low level of equity in education outcomes. Parental backgrounds and home supports have a considerable influence in students' academic achievement.

2. Family Resources and Academic Achievement (Within School Differences)

It has been of interest to scholars understanding of the relationship between parental backgrounds and student's academic achievement (so-called achievement gap). Various types of resources in home and school are likely the main mechanism explain such relationship. First of all, home resources play an important role in student's achievement. It is already well known that a separate space for study allows students to pay more attention to their work (Kim & Lee, 2007). At the same time, resources such as books, computers, and internet connections support students' learning by increasing accessibility of and understanding of various information. Students with limited access to such resources are more likely to be linked to a lower performance in their academic achievement (Barbarin et al., 2006; Bradley & Corwyn, 2002).

Parent's SES also shape their children's thoughts and educational experiences. Parents with low SES are easily exposed to difficulties in dealing with housing problems, which requires them to move often their home. This condition makes it difficult for their children to attend regularly school, which can directly affect academic performance (Hagan, MacMillan, & Wheaton, 1996; Hancock et al., 2017). In addition, Parent's cultural norm may contribute to children's help-seeking strategies, which generated inequalities in the classroom. Calarco (2011) found that students' help-seeking strategies depend on their class. While middle-class students persistently request help from teachers whenever they are struggled with, working-class students often do not ask help even if they were in trouble with. Under such different help-seeking strategies, middle-class students are better able to finish their tasks on time and learn effectively relative to working-class students. Furthermore, high SES parents have a better understanding of the importance of tracking, so they tend to be actively involved in their children's placement (Useem, 1992; Gamoran, 1992; McGrath & Kuriloff, 1999a).

3. School Resources and Academic Achievement (Between School Differences)

School is another factor that affects student's achievements. School-level resources are the main mechanism that explains academic achievement gap between schools (Greenwald, Hedges, & Laine, 1996; Hægeland, Raaum, & Salvanes, 2012). As schools that have a lot of high SES students are likely to have more budget, those schools might be able to hire a quality of teachers, provide curriculum better meet student needs, and maintain small class size (Gamoran, 1987; Jepsen & Rivkin, 2009; Owens, 2018). In such condition, students' academic performance between schools might be divergent.

As with the system in the U.S., in a certain part, schools in Korea are also affected by the size of the region's economy. However, the budget gap among schools is relatively small due to various forms of government's supports. At the same time, it is expected to be less influenced by school-level resources because schools in Korea are required to operate standardized curriculum and need to maintain a certain level of conditions.

Students' academic achievements are also affected by the sharing of intangible resources such as norms, information, and support (Crosnoe, 2004), which are closely related to school-level SES. To be specific, socioeconomic composition in school explains the different density of the parental networks among schools. Middle class parents are more connected, while low class parents are less connected (Horvat, Weininger, Lareau, 2003). With tight networks among parents in the same school, the level of trust is likely high. Then, the exchange of resources actively operate under such condition (Condron, 2009). In addition, high SES parents also negotiate school policies to ensure more favorable environment for their children. Relative to low SES parents, they have a better understanding of how school works and what their children need. High SES parents are also able to utilize their networks, expertise, and information (McGrath & Kuriloff, 1999a; Horvat, Weininger, & Lareau, 2003).

The environment around schools, including residential areas, is also associated with students' learning. For example, people are more connected, actively exchange resources, share norms in areas where many advantaged people live and the rate of residential turnover is low (Sampson, Morenoff, & Felton, 1999). These results suggest that it may not be appropriated contributing the achievement gap between schools simply to the differences in school-level resources.

In contrast, the impact of residential environments in Korea, which are often measured by school-level resources, can be similar to or rather greater than the size of effects in the U.S. Schools in affluent areas may have more options for after-school instructor pools, which will generate a quality of difference in their after-school programs as well as extracurricular activities. Moreover, the percentage of participating in private education in Korea is very high. Considering that the size of the private education market is closely related to nearby housing prices, it is expected that more private education options will be given to students attending high SES schools. At this time, the effects of standardized curriculum operation may not be revealed.

4. Interaction Between Family and School Resources

Although both family and school resources are the key to understand of within and between achievement gaps, relatively few studies have investigated in family and school effects together on academic and social outcomes (Parcel, Dufur, & Cornell Zito, 2010). This is not only because the effect of parents and school is interconnected, but also school policies are often determined by certain groups, such as high SES and White, and run in ways that are in their favor (McGrath & Kuriloff, 1999b). It means that the impact of schools may vary depending on the student's personal background (Crosnoe, 2004).

For example, additional funding for disadvantage school districts in North Carolina helped average students in the school districts to attain higher academic achievement than expected in the absence of the program (Henry, Fortner, & Thompson, 2010). Academically disadvantage students also attained higher scores than would have scored without the program. Although these results indicate that this funding program is beneficial to reduce academic achievement gap between advantaged and disadvantaged school districts, it does not help to reduce inequality within disadvantaged school districts because academically disadvantaged students do not increase more from the funding program compared to academically advantaged students. Alternatively, Stanton-Salazar (2011) suggests that schools can make up for what low SES parents are difficult to meet by providing various types of resources through institutional agents. This result raises the possibility that achievement gap based on individual backgrounds could be alleviated by the school's support.

Ⅲ. Methods

1. Participants

We collected the PISA 2015 data of 5,548 Korean students from 168 schools and 5,217 U.S. students from 161 schools. The target population of this sample is aged between 15 years 3 months and 16 years 2 months when the assessment was offered. The students in this research are typically labeled as first grader in Korean high schools or tenth graders in the U.S. educational system. To select these students, the PISA 2015 applied two-stage cluster sample design in which schools were the units of the first-stage sampling and students within sampled schools were the units of the second-stage sampling. These students completed mathematics assessments and student-parent questionnaires, which means that all missing data were deleted.

2. Variables

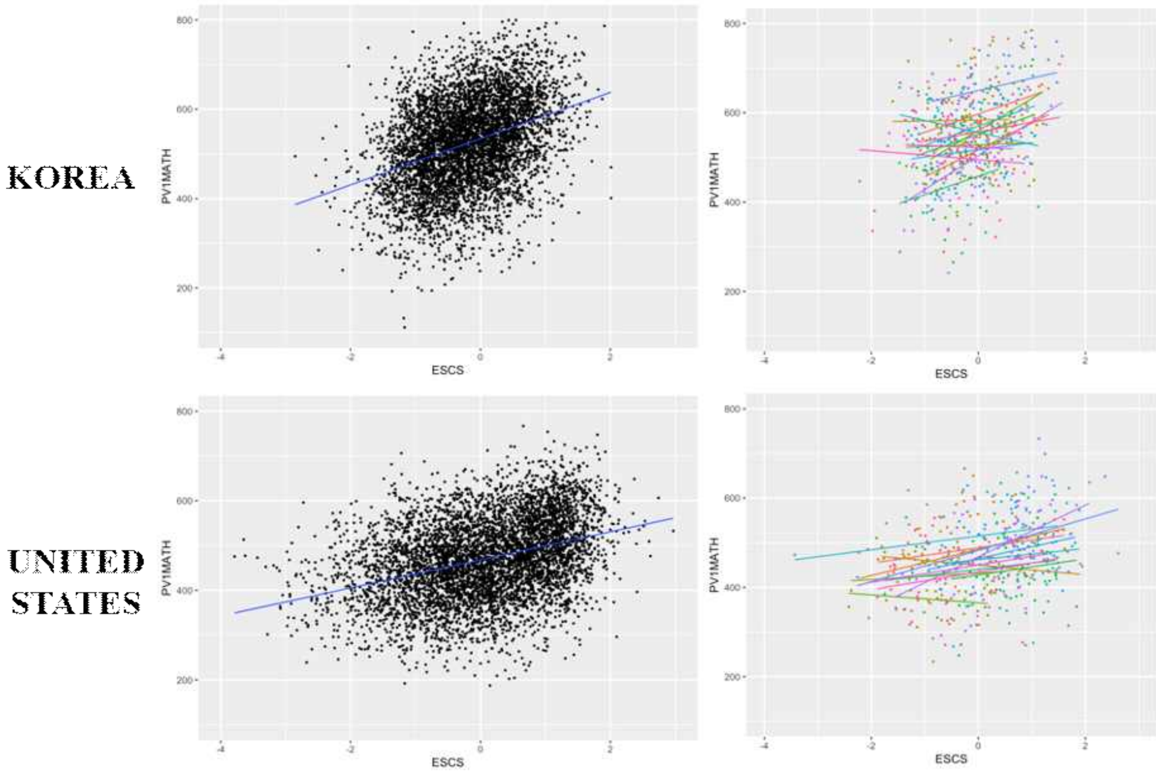
The plausible values of mathematical literacy scores were collected from the PISA 2015 data. The PISA 2015 provided the ten sets of plausible values, which allowed us to find an accurate representation of the relationships between socioeconomic status and mathematical literacy. Foy, Brossman, & Galia, 2012) argued that “by including all available background data in the model, a process known as ‘conditioning,’ or relationships between these background variables and the estimated proficiencies will be appropriately accounted for in the plausible values” (p. 3). Thus, we utilized all plausible estimating the sampling variance for each plausible value and applied the specific procedure described by Chaney et al. (2001) to compute the standard errors or any calculated estimates.

In addition to students' scores of mathematical literacy, we used the variable called “the PISA index of economic, social, and cultural status” (ESCS) to represent students' socioeconomic status. The ESCS scale was established on the indicators of parental education (PARED), highest parental occupation (HISEI), and home possessions (HOMEPOSE) including books in the home (OECD, 2017, p. 36) with application of the principal component analysis. Details of each component of the ESCS are reported in Table 1. Lastly, in the PISA 2015, the ESCS scale was

[Table 1] Questions for the Components of the ESCS scale (OECD, 2017)

Questions			Related Factor	Factor Loading		Reliability	
				Korea	U.S.	Korea	U.S.
Profession	ST014	-What is your mother's main job? -What does your mother do in her main job?	HISEI	0.78	0.84	0.62	0.71
	ST015	- What is your father's main job? - What does your father do in his main job?					
School Education	ST005	-What is the highest level of schooling completed by your mother?	PARED	0.79	0.81		
	ST007	-What is the highest level of schooling completed by your father?					
Vocational Training	ST006	-Does your mother have any of the following qualifications?					
	ST008	-Does your father have any of the following qualifications?					
Home Possessions	ST011	-Which of the following are in your home?*	HOMEPOS	0.73	0.74		
	ST012	-How many of these are there at your home?*					
	ST013	-How many books are there in your home?					

* See the PISA student questionnarrie for details (https://www.oecd.org/pisa/data/CY6_QST_MS_STQ_CBA_Final.pdf)



[Fig. 1] Scatter plots of all students (left) and students in 15 schools randomly selected (right) in each country. We used the first plausible value of mathematical literacy. The blue lines indicate the linear regression model not including school-level ESCS.

"transformed with zero being the score of an average OECD student and one being the standard deviation across equally weighted OECD countries" (OECD, 2017, p. 37). We acknowledged that the reliability coefficients are somewhat low in both Korea and the U.S. showing a difference of 0.1. Low reliability indicates that there could be a large amount of variances in the scores is due to random errors. We suggest careful interpretation considering errors in measurement and loss of power of hypothesis tests (Osborne, 2013). This is an issue addressed by data collection of the OECD, not our analysis procedure.

3. Hierarchical Linear Modeling

In this research, we applied the hierarchical linear modeling (HLM) approach to address the research questions. The HLM approach was considered initially because of the sampling design in the PISA 2015. Additionally, we examined the relationship between ESCS and mathematical literacy scores at a student level in a descriptive manner before applying a regression analysis. Without consideration of schools, the scatter plot (left graphs in Figure 1) shows that there is a positive relationship between ESCS and mathematical literacy in both countries. However, when students are grouped by school, those relationships within schools seem not only weaker than those without grouping but also heterogenous across schools. The right graphs in Figure 1 show the linear regression lines for 15 schools randomly selected in each country. This might indicate that a single level model cannot appropriately explain the relationships between socioeconomic status and mathematical literacy. All graphs in Figures suggest that we needed to consider a nested structure by school and apply multilevel analysis, particularly the HLM approach.

Furthermore, we calculated the intraclass correlation coefficients (ICC), which show the proportion of the variances in students' mathematical literacy scores explained by the group/school membership. A high ICC questions relationships in single level models (Snijders & Bosker, 1999) while a considerable portion of variances in students' mathematical literacy are attributed to school features rather than individuals' characteristics. Although there are various answers about how high ICCs are enough, Kim, Solomon, and Zurlo (2009) recommended an ICC over 0.25 as a criterion to apply the HLM approach in general. The ICCs were 0.28 for Korean students and 0.21 for U.S. students. The ICC of Korean students supported the HLM approach whereas the ICC of the U.S. students was close but less than 0.25. Comprehensively considering Figures 1 and ICCs, we decided to apply the HLM approach to data of both countries.

Considering the HLM approach for each country separately, we included students' ESCS as the level-1 variable and the mean ESCS within schools as the level-2 variable. The foundational equations for the hierarchical models are as follows: For the multilevel model seen with consideration of school ESCS,

Level-1 Model (Student Level):

$$MATH_{ij} = \beta_{0j} + \beta_{1j} \times (ESCST_{ij}) + r_{ij},$$

Level-2 Model (School Level):

$$\beta_{0j} = \gamma_{00} + \gamma_{01} \times (ESCSM_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} \times (ESCSM_j) + u_{1j}$$

where $ESCST_{ij}$ indicates ESCS of student i centered around the mean of school j; $ESCS_{ij}$ indicates ESCS of student i; $ESCSM_j$ indicates the uncentered mean ESCS of students within school j; γ_{00}, γ_{10}, γ_{01}, and γ_{11}, are school-level regression coefficients; r_{ij} are student-level residuals; $u_{0j}$and u_{1j} are random effects associated with student-level intercepts and slopes, respectively.

We applied unconditional models that impose no restrictions on the estimated values. For the HLM analysis, we utilized the restricted maximum likelihood estimation. Moreover, because our main research interest was on the student level (the relationships between students' ESCS and mathematical literacy), we included "the final trimmed nonresponse adjusted student weight" (W_FSTUWT) to eliminate possible biases from stratification, nonresponse, or disproportions of subsamples (OECD, 2017). The HLM software version 7.01 (Raudenbush, Bryk, & Congdon, 2013) was employed for the analysis.

Ⅳ. Results

1. Descriptive Statistics

We had descriptive statistics of mathematical literacy at the student level and those of ESCS at both student and school levels. First, Table 2 reports descriptive statistics of the ESCS and average scores of each literacy at the student level. Korean students' weighted average score ranged from 522.85 to 526.02 for mathematical literacy. Considering that the OECD average was 490, those average scores of Korean students seemed significantly higher than the OECD average although we do not have any hypothesis tests. Korean students' average ESCS score was -0.20, which is lower than the OECD average of 0. The correlation coefficients between mathematical literacy plausible values and ESCS ranged from 0.34 to 0.38.

The weighted means of U.S. students were lower than those of Korean students: they ranged from 468.73 to 470.46 for mathematical literacy. Simultaneously, those averages seemed less than the OECD average. The average ESCS of U.S. students was 0.07, which is similar with the OECD average and greater than the average ESCS of Korean students. The correlation coefficients between each set of mathematical literacy plausible values and ESCS were also similar with Korean results ranging from 0.28 to 0.37.

Second, Table 2 also shows descriptive statistics of ESCS at the school level. The unweighted average ESCS score of Korean schools (−0.21) was close to the weighted average ESCS at the student level (−0.20), but less than that of U.S. schools (0.08). The standard deviations of school ESCSs were 0.33 for Korea and

[Table 2] Descriptive Statistics of Mathematical Literacy Plausible Values and ESCS scale

Variable		Korea		United States	
		Weighted Mean (SD)	Correlation With ESCS	Weighted Mean (SD)	Correlation With ESCS
Student Literacy Plausible Values	1st	524.45 (99.69)	0.36	470.17 (88.84)	0.36
	2nd	523.34 (99.45)	0.35	470.32 (89.54)	0.37
	3rd	525.10 (98.73)	0.37	468.73 (88.51)	0.38
	4th	525.98 (99.32)	0.35	468.33 (88.67)	0.36
	5th	523.62 (100.89)	0.37	469.80 (87.56)	0.36
	6th	522.79 (99.98)	0.35	469.36 (87.07)	0.36
	7th	523.63 (99.24)	0.34	469.09 (88.57)	0.36
	8th	522.85 (99.71)	0.36	470.46 (87.34)	0.35
	9th	526.02 (100.10)	0.36	469.58 (88.45)	0.36
	10th	523.25 (100.13)	0.37	470.45 (90.08)	0.36

	Unweighted Mean	Range	Unweighted Mean	Range
Student ESCS	-0.20 (0.68)	(-4.08 2.01)	0.10 (1.00)	(-3.79 2.97)
School ESCS	-0.21 (0.33)	(-1.06 0.68)	0.07 (0.54)	(-1.65 1.13)

0.54 for the U.S. Each standard deviation was about a half of the standard deviation at the student level (0.68 for Korea and 1 for the U.S.). In addition, the ranges of the school ESCSs were (-1.06 0.68) for Korea and (-1.65 to 1.13) for the U.S. In other words, schools in the U.S. were more heterogeneous than schools in Korea regarding school ESCSs.

2. HLM Results

Table 3 shows the estimation results of the multilevel models with school ESCSs. In the multilevel model with school ESCS, the regression coefficients for the level-1 intercept β_0, γ_{00} and γ_{01} indicate the intercept and the slope of the school-level linear model respectively. The coefficient γ_{10} for the ESCS slope β_{1j} represents the slope of ESCS at the student level within schools where the average ESCS of the schools is 0. γ_{11} shows the change in the slope of ESCS at the student level as the school ESCS increase by 1.

Based on those meanings of the regression coefficients, the linear models of Korean students at the school level had the intercept of 548.61 for mathematical literacy. Those models also had the slopes of 131.05. The linear models of the U.S. students had the intercept of 463.60 for mathematical literacy. In addition, the slope was 55.70 for the U.S. students, However, the intercept of the U.S. model for mathematical literacy is lower compared to the Korean model.

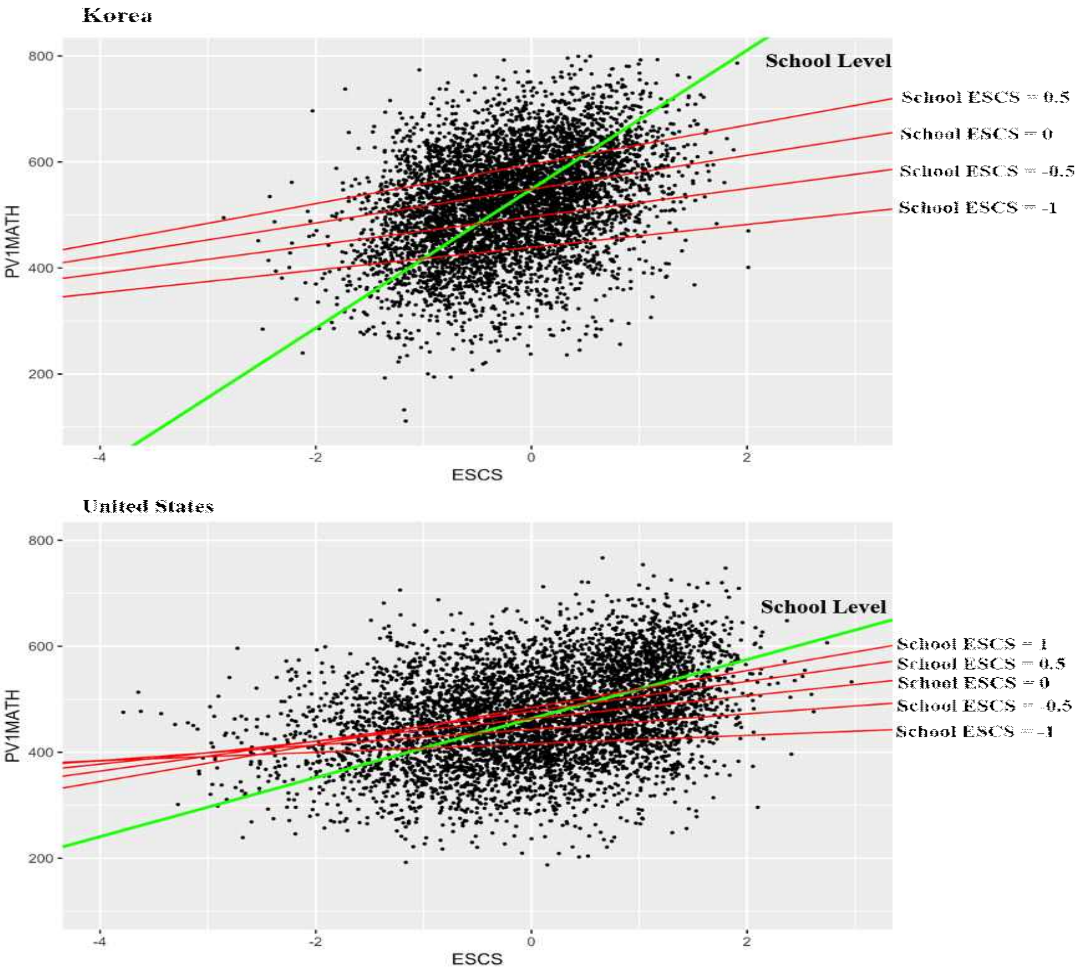
Based on the estimations of the fixed effects, the linear models at different levels of school ESCSs (-1, -0.5, 0, 0.5, and 1) are constructed as seen in Tables 4 and visualized in Figure 2.

Focusing on the results of the random effects in Table 3, we find that variances in the student-level ESCS slopes are significant in the U.S, but not in Korea at the alpha 0.05. This indicates that there is systematic variance in the student-level slopes in the U.S., which need to be accounted for with other school-level variables. Korean results about the random effects indicate that researchers are able use simpler models to explore the relationships between ESCS and mathematical literacy using the HLM approach. The most important finding in Figure 2 is that the U.S. school-level slopes for mathematical literacy (55.70) are remarkably smaller than Korean school-level slopes (131.05). The patterns of Korean and the U.S. models will be explained and interpreted with the results of mathematical literacy in detail.

As seen in Table 4, at the student-level, the slope

[Table 3] Hierarchical Linear Modeling Results

Fixed Effects: ESCST	Korea			United States		
	Coeff.	SE	p-value	Coeff.	SE	p-value
For level-1 Intercept, β_{0j}						
Level-2 Intercept, γ_{00}	548.61	3.08	< 0.001	463.60	2.55	< 0.001
ESCSM, γ_{01}	131.05	7.97	< 0.001	55.70	4.60	< 0.001
For ESCS slope, β_{1j}						
Level-2 Intercept, γ_{10}	31.95	2.85	< 0.001	21.47	1.61	< 0.001
ESCSM, γ_{11}	10.35	7.47	0.169	13.48	2.53	< 0.001
Random Effects	**Var.**	**SD**	**p-value**	**Var.**	**SD**	**p-value**
Level-1 Intercept, u_{0j}	914.67	30.24	< 0.001	743.67	27.27	< 0.001
ESCST slope, u_{1j}	54.43	7.38	0.105	37.57	06.13	0.043
level-1, r_{ij}	6881.86	82.96		5740.60	75.67	



[Fig. 2] Multilevel analysis results. The scatter plots include ESCS and the first plausible values of mathematical literacy. The red lines show the results of the student-level models while the green lines indicate the results of the school-level models.

[Table 4] Student-Level Models based on Multilevel Analyses

School-Level Model		Korea			United States		
		Intercept		Slope	Intercept		Slope
		548.68		131.05	463.60		55.70
Student-Level Model	School ESCS	School Literacy Mean	Intercept	Slope	School Literacy Mean	Intercept	Slope
	−1.0	417.63	439.18	21.55	407.90	415.90	7.99
	−0.5	483.16	496.52	26.73	435.75	443.12	14.73
	0	548.68	548.68	31.90	463.60	463.60	21.47
	0.5	614.21	595.67	37.08	519.29	484.34	34.95

of ESCS within schools are likely to increase as school ESCSs increase in both Korea and the U.S. In the results of Korean students, we do not find evidence for the significantly different slopes within schools by school ESES although the slopes within schools increase by 10.35 as the school ESCSs increase by 1. However, the differences in the intercepts are significant (31.95, $p < 0.001$). Because these parallel slopes, school ESCSs can be very significant to find Korean students' expected scores for mathematical literacy. For example, Korean students having ESCS of 0 – OECD average – are expected to have 439.18, 496.52, 548.68, and 595.67 (the intercept of each model in Table 4) when their school ESCSs are -1, -0.5, 0, and 0.5 respectively. In other words, Korean students are likely to have higher mathematical literacy scores by about 100 than their peers with the same ESCS as the differences between the school ESCS is 1. Because the standard deviations of mathematical literacy are also around 100 as seen in Table 2, the gaps between any pair of those scores are critical to understand the relationships between ESCS and mathematical literacy.

We can interpret the results of U.S. students in an analogous way. The slopes and the intercepts within schools increase by 13.48 and 21.47 ($p < 0.001$ for each) respectively as the school ESCSs increase by 1 in the U.S. These findings are statistically significant, which indicates that linear models at the student level are not parallel with different school ESCSs. The non-parallel lines in Figure 2 show that students with low ESCS seem to have similar scores of mathematical literacy, whereas students with high ESCS could have different scores by their school ESCSs. Specifically, students with ESCS of -1 are likely to score 407.90, 428.38, 442.13, 449.13, and 449.39 when their school ESCSs are -1, -0.5, 0, 0.5, and 1 respectively. However, students with ESCS of 1 are expected to have 423.89, 4578.85, 485.07, 505.55, and 519.29. The score gaps among students who have the same ESCSs but different school ESCSs become bigger when their ESCS is high (41.49 when ESCS is -1 and 95.40 when ESCS is 1).

V. Discussion and Conclusion

This research aimed to articulate the relationships between students' socioeconomic status and mathematical literacy by analyzing the PISA 2015 data with a hierarchical model. Additionally, we compared the two models of Korea and the U.S. Focusing on the findings with multilevel analysis, socioeconomic status and mathematical literacy are strongly related at the school level in both Korea and the U.S. The degree of strength is significantly larger in Korea compared to the U.S. Additionally, there is evidence that the within-school relationships between socioeconomic status and mathematical literacy are heterogeneous in the U.S., but not in Korea. The slopes at the student level within schools are remarkably smaller than the slope at the school level. This finding indicates that school-level socioeconomic status is more important than individual socioeconomic status to predict one's mathematical literacy, especially in Korea.

The findings allow us to better understand inequity – the literacy gap between students from high and low socioeconomic status – while suggesting the importance of school-level socioeconomic status. These gaps between students in different schools become quite bigger as average socioeconomic statuses increase. Specifically, such gap between schools with average ESCSs of 0 and 1 is close to the standard deviations of Korean students (about 100). Thus, this supports that school-level achievement cannot be ignored to understand Korean students' achievement gap between students from high and low socioeconomic status.

In the U.S., we note that students from low SES are likely to have similar literacy scores although they attend schools with different the socioeconomic composition of schools. Compared to the results of Korean students, the slope of students' socioeconomic status at a school level is smaller. Furthermore, we found U.S. students' relationships between ESCSs and mathematical literacy scores moderated by the socioeconomic composition of schools, which is not found in the Korean results. These two findings together lead to similar literacy scores of low SES students regardless of the average SESs in their schools as seen in Figure 2. These similar scores probably indicate minimal interactions between students' resources and school resources in the U.S. Otherwise, it is possible that U.S. schools with the high socioeconomic composition cannot help low-SES students well.

We further highlight the relationships between U.S. students' ESCSs and mathematical literacy in schools with low socioeconomic composition. The slope coefficient is 7.99 for mathematical literacy when U.S. schools have average SES of -1. Thus, we expect that students with ESCSs of -1 and 1 have a gap of approximately 16 points in mathematical literacy, which is about 0.2 standard deviations of the U.S. students. This finding seems aligned to the definition of equity in education, namely the minimum effects of students' socioeconomic background. However, it is still uncertain why and how such inequity in schools with low average SESs show equity.

As a secondary analysis using large-scale international database, answering reasons for the differences between Korea and the U.S. in terms of equity in education is beyond the scope of this research. Despite of this limitation, it is necessary to discuss the findings in depth to suggest proper interpretation with confounding factors. We acknowledge that communalities and differences of the two educational contexts should be considered in interpretation and discussion of the findings. Thus, addressing this limitation, we will provide possible explanations showing paths of further research, particularly based on Korean contexts.

Considering Koreans' efforts for equality across schools, this large effect might come from the resources of the local communities including schools rather than the resources only in schools. Among such resources, we speculate that the influential factor on the school-level finding is supplementary private education including personal tutoring or private education institutions called hagwon (OECD, 2016a). There are very high demands of Koreans for such private education, called educational fever (Kang & Hong, 2008). Although individual students are from a low socioeconomic background, their parents could attempt to offer supplementary education to them as peers in their schools do. This could result in parents with a low socioeconomic background spending a large proportion of their income for their children's supplementary education (Kim, Hwang, & Park, 2019). Thus, the strong relationship between socioeconomic backgrounds and achievement at the school level seems to be somewhat contradictory to Korean policy to equalize schools. However, we do not argue that this policy has failed. Rather, the findings strongly support the influence of supplementary private education on achievement gaps in Korea, which Kang and Hong (2008) argued.

The above argument indicates that the influence of socioeconomic background at the student level could be small in Korea although we examine the positive relationships between socioeconomic backgrounds and mathematics achievement within schools. The similar degrees of those relationships regardless of average socioeconomic status in schools also support that differences in individual socioeconomic backgrounds could be weakly related to inequity in mathematics education. Considering Korean contexts in interpretation of the findings, we highlight that the strong relationships at the school level might not reflect the differences among schools, but local communities including supplementary private education.

In addition, curricula have significant influences on students' learning opportunities and their achievement. In other words, students can use their resources interacting with school resources in different ways by curriculum. For this reason, we highlight differences in responsibilities to select school curriculum overseen by principals, teachers, school boards, local/regional authority, and national authority. In Korean, school principals and teachers have 80.6% of the responsibilities (12th highest) while it is 53.2% in the U.S. (40th highest; OECD, 2016b, p. 117). Koreans' larger responsibilities for selection of school curriculum could be related to large effects of school-level ESCS. Whereas local/regional authority in the U.S. has more responsibilities than the counterparts in Korea. This could reduce the effects of school-level ESCS in the U.S. However, follow-up studies on supplementary private education in Korea and the responsibilities to select school curriculum should be followed to answer the above speculations.

It is necessary to consider that the PISA defines and evaluates students' mathematical literacy in its own way. This indicates that we need to consider what assessments aim to measure and what mathematics achievement represents. Analysis with other databases like the TIMSS can yield different results. Moreover, further research is required with multiple sources of students' socioeconomic status and academic achievement. Some assessments can be more or less sensitive to students' and schools' resources.

This research articulates the achievement gaps between high and low socioeconomic backgrounds and those gaps are related to school-level socioeconomic backgrounds. The findings in this research suggest several paths for further research. International comparisons help educators to understand how Korean educational contexts are intertwined with the relationships between socioeconomic status and achievement. In addition, studies using other data can contribute to better understanding about equity in Korean mathematics education. Particularly, mathematical literacy measured in the PISA 2015 might not fully correspond to the purpose of Korean mathematics education. It would be better if researchers utilized assessment data aligned with Korean curriculum and educational purpose.

Lastly, this research also reminds educators and policymakers of the implications suggested in the prior studies: people should not simply mimic other education systems. Korea is one of the countries showing very high achievement in international comparison studies. However, the achievement gaps between low and high socioeconomic status are examined at the school levels. These findings are interweaved with the characteristics of Korean students like high demands for supplementary private education as well as school characteristics like curriculum selection. Thus, it is necessary to first understand achievement, the equity issue, and contexts comprehensively. Then, educators can improve their own education systems based on Korean students' high achievement.

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