Students' Mathematics Learning from Kindergarten through 8th Grade: The Long-Term Influence of School Readiness

Katerina Bodovsky & Ming-Jong Youn[1]

1) Department of Education Policy Studies, Pennsylvania State University, United States of America.

Date of publication: June 25th, 2012

To cite this article: Bodovsky, K., Youn, M. (2012). Students' Mathematics Learning from Kindergarten through 8th Grade: The Long-Term Influence of School Readiness. *Intnernational Journal of Sociology of Education,* 1(2), 97-122. doi: doi: 10.4471/rise.2012.07

To link this article: http://dx.doi.org/10.4471/rise.2012.07

RISE - International Journal of Sociology of Education Vol. 1 No. 2 June 2012 pp. 97-122

Students' Mathematics Learning from Kindergarten through 8th Grade: The Long-Term Influence of School Readiness

Katerina Bodovsky & Ming-Jong Youn
The Pennsylvania State University

Abstract

We employed a large nationally representative data set for the U.S. elementary school students, the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K), to investigate the relationships between school readiness, measured in the fall of kindergarten, and students' mathematics learning during the elementary and middle school years, including 8th-grade math course-taking. Main findings: School readiness (math and reading scores, and approaches to learning) showed a strong positive relationship with math scores at the end of each tested grade (1st, 3rd, 5th, and 8th). Students who entered kindergarten with higher math score tended to show a lower rate of math growth. Higher school readiness was strongly and positively associated with a likelihood that a student is taking Algebra I or above in 8th grade. Findings suggest that for minority students and students from lower SES backgrounds, improved school readiness would increase their math achievement.

Keywords: family-school connections, parental involvement, socioeconomic disparities, early childhood Longitudinal Study.

2012 Hipatia Press
ISSN 2014-3575
DOI: doi: 10.4471/rise.2012.07

Research has shown that children from different social backgrounds come to school with different levels of pre-math and pre-reading skills, as well as learning related behavior, which together constitute 'school readiness'. Specifically, children living in poverty, children of single mothers and minority children are at higher risk of being "unready to school" (Duncan and Magnuson, 2005; Farkas & Hibel, 2008). Last several decades of studies also showed the existing socio-economic and ethnic differences in academic achievement among middle and high school students. The empirical question is then whether school readiness (or un-readiness) influences children's subsequent educational trajectories after taking into account their socio-economic and demographic characteristics.

In this study we investigated how school readiness (measured at the beginning of kindergarten) affects students' mathematics learning through the end of middle school, i.e., end of 8th grade. Specifically, the study had three main objectives: a) to estimate growth in students' mathematics achievement during the elementary and middle school years as a function of school readiness; b) to examine mathematics courses taken in the 8th grade as a function of school readiness net of other student- and school-related factors; and c) to examine whether these relationships differ for various groups of students, defined by their gender, race/ethnicity, and family socioeconomic status. To address these objectives, we employed a large nationally representative data set for elementary school students, the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K), including the most recently available 8th-grade wave of data.

Theoretical background

Mathematics learning and achievement

The literature offers no consensus on whether children who start school with low levels of knowledge improve, remain at the same relative position, or fall even further behind their peers over time. Similarly, there is no consensus on whether students who begin school with high achievement maintain their high rate of learning or assume a slower pace over time. Several studies have shown that higher beginning achievement is associated with lower subsequent learning rates, possibly due to a combination of regression to the mean and either instructional or testing ceiling effects (Bloom, 1976, 1984; Brown & Saks, 1986; Phillips, Norris, Osmond & Maynard, 2002). Other studies, however, have indicated that cognitive outcomes show strong continuity over time; earlier school achievement is strongly and positively related to later achievement; and variation among students tends to increase over time (Alexander, Entwisle, & Horsey, 1997; Bast & Reitsma, 1997; Brophy, 1982; Duran & Weffer, 1992).

Several studies have specifically reported an increasing disparity in students' mathematics achievement throughout elementary and middle school. One study that followed children from preschool to 2nd grade found that those who started preschool with more knowledge showed faster rates of learning (Aunola, Leskinen, Lerkkanen & Nurmi, 2004). Bodovski and Farkas (2007) reported that students who began kindergarten with the lowest levels of math achievement also showed the least growth up to the spring of 3rd grade. Williamson, Appelbaum, and Epanchin (1991) found that individual differences in mathematics achievement increased between the 1st and 8th grades, with students' initial achievement positively correlated with their growth rate. This study, however, used a relatively small (667 cases), non-representative sample. Thus, using longitudinal data from a nationally representative sample of students is essential to examining the mathematics growth trajectories of different groups of children. Reardon and Galindo (2009) made a significant step in this direction while examining race/ethnic achievement gaps between fall of kindergarten and spring of 5th grade using the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K). They found that although in the fall of kindergarten both Black and Hispanic students had math and reading scores significantly lower than those of White students, different learning trajectories were observed for these groups over the period of six years: the Black-White gap steadily increased, particularly in math, whereas the Hispanic-White gap narrowed by about one-third (Reardon & Galindo, 2009, p. 869).

Mathematics course-taking

Studying mathematics learning trajectories does not only mean estimating the scope of skills and knowledge acquired by children. The learning of mathematics is sequential in nature; at higher levels (at the end of middle school and up) it involves taking specific courses that are hierarchically organized, starting with general math and pre-algebra and up to trigonometry and calculus (Riegle-Crumb, 2006; Schneider et al., 1998; Stevenson et al., 1993). The majority of existing studies of mathematics course-taking focus on the courses students take in high school, either as an outcome in and of itself or as a predictor of college attendance and major (Ayalon, 2002; Finn, Gerber, & Wang, 2002; Horn & Bobbitt, 2000; Kelly, 2009; Schiller & Muller, 2003; Trusty, 2002; Tyson, Lee, Borman & Hanson, 2007). Within this research, and particularly in the studies that have used the National Educational Longitudinal Study (NELS: 88), 8th-grade math courses taken by students have served as a baseline for the investigation of later outcomes. Indeed, findings based on NELS and other data sources have shown that the beginning of high school-level math skills has a significant association with course selection in high school and explains, at least in part, social class and racial gap in high school achievement (Kelly, 2009; Ma, 2000; Ozturk & Singh, 2006; Wang & Goldschmidt, 2003). In particular, algebra is considered a “mile stone” for mathematics and science sequence and has a direct positive effect on growth in mathematics achievement (Gamoran & Hannigan, 2000; Matthews & Farmer, 2008).

An important contribution to this literature was made by Riegle-Crumb (2006), who investigated math course-taking patterns by gender and race/ethnicity using data from Adolescent Health and Academic Achievement (AHAA). Not only was the initial math course taken at the beginning of high school consequential for math courses taken at the end of high school, but the benefits of taking these courses varied by student gender and ethnicity: African-American and Latino males had lower returns from taking algebra in 9th grade compared to White males. In another study using Educational Longitudinal Study data, Riegle-Crumb and Grodsky (2010) compared social class and race/ethnic gaps in students' achievement by math course stratum: students who took advanced courses vs. those in regular courses. Although being in advanced math classes improved achievement for all students, the authors found that race/ethnic gaps were actually larger among students in advanced math courses (pre-calculus and calculus). These findings highlight the importance of understanding the processes of accumulating knowledge prior to high school, not only in terms of specific courses taken but also the level of skills and knowledge students possess. If students do not have adequate preparation, they are at risk of falling behind their more advanced peers even if they take the same courses.

Level and nature of mathematics skills at the end of middle school are crucial to advanced course-taking in high school in both mathematics and science and to later success in post-secondary education (Hallinan & Kubitschek, 1999; Kelly, 2009; Lee & Frank, 1990; Lucas, 1999). Given findings that inequality in math achievement is being exacerbated by high school course selection, which is based on previous achievement, Wang and Goldschmidt (2003) called on the educational community "to identify elements that potentially limit mathematics success as early as possible" (p. 15) and highlighted the importance of improving early math skills for all students in order to prevent disparities in 8th grade and beyond. To that end, investigating the relationship between school readiness and subsequent achievement seems critically important.

School readiness

Using six longitudinal data sets Duncan and colleagues (2007) examined the links between school readiness and subsequent academic achievement, measured (depending on a data set) from third to eighth grade. They found that, uniformly, the skills and knowledge exhibited at school entry have significant associations with math and reading achievement in later years. Specifically, early math skills showed the greatest predictive power, followed by reading and then attention skills. Interestingly, these relationships were universal for boys and girls, and for children from higher and lower socioeconomic backgrounds (Duncan et al., 2007). These findings are consistent with those from Alexander and colleagues based on the Beginning School Study, which showed that early exhibited achievement is significantly associated with subsequent achievement and attainment, including high school dropout rates (Alexander, Entwisle & Horsey, 1997; Entwisle & Alexander, 1996). More recent study by Hooper and colleagues (2010) replicated the findings by Duncan et al. (2007) and found that early math, reading and attention were significant predictors of math and reading achievement up to the 8th grade.

If school readiness is consequential for subsequent achievement, what factors contribute to it? Farkas and Hibel (2008) undertook a thorough examination of several factors, including child and family demographic characteristics (gender, race/ethnicity, poverty status, parental education, occupation and income), birth weight, parental practices and parental involvement, type of preschool attended, and federal program participation to determine who is ready/unready to enter school. They found that low parental education, living in poverty, and living in a non-English-speaking home predicted school "un-readiness". Also, boys, Black and Hispanic students, and students from larger families exhibited low school readiness. These findings are consistent with those from other studies that examined the factors shaping school readiness. Duncan and Magnuson (2005) focused on four components of family backgrounds that influence children's school readiness: parental education, family income, family structure, and neighborhood conditions. Combined, these factors explain about one-half of a standard deviation of the test score gaps between White and minority students.

Our investigation is founded on previous studies that linked school readiness to a subsequent achievement. We contribute to current knowledge by examining three specific outcomes of school readiness. First, we estimate the effects of school readiness on end-of-year math achievement in the 1st, 3rd, 5th, and 8th grades. Second, we link school readiness to the math achievement growth rate between 1st and 8th grades. Finally, we estimate the effects of school readiness on the likelihood that a student is enrolled in advanced math course in 8th grade (Algebra I or above). Our study addresses two important policy issues. First, there is a wide consensus among educators and policy makers regarding the need for rigorous math preparation for all students to ensure that they continue their education in college and successfully participate in an increasingly competitive labor force. To that end, investigation of the factors that influence math achievement throughout children's school careers and specifically at the time point preceding high school (the end of 8th grade) is essential. Second, the issue of early childhood education and the importance of early acquired skills and behaviors that constitute school readiness are consistently found in the U.S. in both academic and political discourse. Socioeconomic, racial and ethnic, and gender disparities in school readiness have been widely documented (Downey et al., 2004; Farkas & Hibel, 2008; Ready et al., 2005; Reardon & Galindo, 2009). However, no study has linked children's school readiness to their math achievement growth throughout the end of middle school and to the type of math course they are taking, using a large, nationally representative sample of U.S. students.

Data and Method

Data

The data for this study came from the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS–K). The ECLS-K, sponsored by the U.S. Department of Education, National Center for Education Statistics, selected a nationally representative sample of kindergartners in public and private schools in the United States in fall 1998 and followed these children through the spring of 2007.

Sampling for the ECLS-K involved a dual-frame, multistage sampling design. The first stage included the selection of 100 primary sampling units (PSU—counties and county groups). Public and private schools were then selected from PSUs, and children were sampled from the selected schools. By following students who entered kindergarten in 1998 through 8th grade, the ECLS-K data provide the first large-scale, nationally representative sample of children as they age through the elementary and middle school years. Because we employed growth curve modeling, we utilized all cases for which the mathematics scores were available for at least three time points. The final analytical sample consisted of 12,256 students and 1,183 schools . The comparison between the original full and analytical samples revealed that our analytical sample included fewer Hispanic students (12% vs. 18%), slightly more Asian students (5% vs. 3%) and students of Other Races (6% vs. 4%). There were no significant differences in SES, gender, and family structure.

Method

The data analysis had three parts. First, we examined how school readiness affects children's math score at the end of each tested grade (1st, 3rd, 5th and 8th). In these data students are clustered within schools; therefore, the usual ordinary least squares (OLS) regression assumption of completely independent observations may be violated because students in the same school tend to be similar on unmeasured variables. If OLS methods are used on these data, this correlation will be captured in the error term, violating the OLS assumption of the independence of error terms and leading to biased estimates of standard errors. To correct for this we employed multivariate regressions adjusted for sample clustering in school using STATA.

Second, we used growth curve models utilizing Hierarchical Linear Model (HLM) to analyze the effect of school readiness on the growth of math achievement from the 1st through 8th grades, as shown in the models:

Model:
Equation (1):
Level 1: Measurement model
$Yij = [\pi 0j + \pi 1j*(\text{Grade}) + \pi 2j*(\text{Grade square}) + \varepsilon ij]$
Level 2: Student model
$\pi 0j = [\beta 00 + \beta 01 *(\text{School readiness}) + \beta 02*(\text{Student background characteristics}) + \mu 0j]$
$\pi 1j = [\beta 10 + \beta 11*(\text{School readiness}) + \beta 12*(\text{Student background characteristics}) + \mu 1j]$
$\pi 2j = [\beta 20 + \mu 1j]$

Level 1 was a repeated measures model in which the dependent variable was the math achievement at grade i for student j. To avoid multicollinearity among time points, the Grade variable was centered so that it took on the value of zero in the 5th grade. Thus, π0j was the expected outcome for that child in the spring of 5th grade. π1j was the learning rate (slope) for student j during the calendar year, and π2j was the math learning acceleration (quadratic) for the student. At the student level (level 2), each level 1 outcome functioned as a dependent variable predicted by school readiness, holding constant other predictors in the model.

Finally, in the third part of the analysis, to answer our research question about the relationship between school readiness and math class taken in 8th grade, we estimated the likelihood that a student had taken an advanced mathematics class defined as Algebra I or above. The advanced mathematics class was a dichotomous variable; therefore, a multi-level logistic regression with binary outcome was used (two levels of hierarchical linear models: students nested within schools).

The regression models involved sequentially entering background variables (SES, race, gender, age, grade), and school readiness. A typical equation was specified as follows:

$$\mathrm{Log}\left(\frac{p}{1-p}\right) = [\beta_{0k} + \beta_{1k}\,(\text{Student Background Characteristics})_{jk} + \beta_{2k}\,(\text{School readiness})_{jk},$$

where p= probability of a student taking an advanced mathematics course

$$\beta_{0k} = {}_{[\gamma 0k} + {}_{\gamma 1k}\,(\text{School Characteristics })_{k} + {}_{u0k},$$

$$\beta_{1k} = {}_{\gamma 0k} + {}_{\gamma 1k}\,(\text{School Characteristics})_{k} + {}_{u1k]}$$

In the next step, the interaction effects between school readiness and student's gender, race/ethnicity, and family SES were examined on the likelihood of a student taking an advanced mathematics class (each interaction term was entered into the model separately):

$$\mathrm{Log}\left(\frac{p}{1-p}\right) = [\beta_{0k} + \beta_{1k}\,(\text{Student Background Characteristics})_{jk} + \beta_{2k}\,(\text{School Readiness})_{jk} + \beta_{3k}\,(\text{School Readiness }_{jk}\text{* SES}_{jk}) + \beta_{4k}\,(\text{School Readiness jk* Female}_{jk}) + \beta_{5k}\,(\text{School Readiness }_{jk}\text{* Race }_{jk})]$$

Variables

Dependent variables

Our first dependent variable was student's math achievement. We employed the mathematics achievement variables that are scaled tests administered to children in the spring of 1st grade (2000), spring of 3rd grade (2002), spring of 5th grade (2004), and spring of 8th grade (2007). Scoring was based upon Item-Response Theory (IRT), so scores could be compared longitudinally (DoE, 2004). The literature suggests that academic performance over this time span is important and will be reflected in both high school grades and ultimate educational attainment (Entwisle, Alexander & Olson, 2005).

The 8th-grade teacher questionnaire included the question: "which of the following best describes this student's mathematics course?" The options were: general mathematics; introduction to Algebra/Pre-algebra; Algebra I; integrated or sequential mathematics (course that includes high school algebra and geometry); Algebra II; and Geometry. We created a new variable, Advanced Math Class, that was equal to 1 if a student took Algebra I and above, and was equal to 0 if otherwise.

School readiness

Following Duncan et al.'s (2007) findings regarding what constitutes school readiness, we used the following three items:

Math score: Standardized IRT Test of Mathematics Achievement in the fall of kindergarten. The test was directly administered to children by NCES staff.

Reading score: Standardized IRT Test of Mathematics Achievement in the fall of kindergarten. The test was directly administered to the children by NCES staff.

Approaches to learning: Composite scale based on six items measuring teacher's judgment in the fall of K of child's persistence at tasks, eagerness to learn, attentiveness, learning independence, flexibility, and organization. It has been shown that in both kindergarten and 1st grade, and net of prior test scores and reading ability group placement, this variable significantly affects future student test scores and reading ability group placement (Tach & Farkas, 2006). Also, in another study based on ECLS-K data Bodovski and Youn (2011) found that when the three teacher-judged student behavior measures (approaches to learning, externalizing and internalizing behavior problems) are used together to predict later test scores, net of prior test scores, approaches to learning is by far the most powerful predictor.

Family background characteristics

SES: A continuous composite measure of socioeconomic status, including parents' education, parents' occupational prestige, and household income.

Black, Hispanic, Asian, Other race: Dummy variables; Non-Hispanic White is the reference group.

Male: Dummy variable; female was the reference group.

Number of siblings: A continuous measure of the number of siblings.

Family structure: 2 dummy-coded variables: single-parent families; other families (non-relative care, adoptive parents, remarried parents). Two biological married parents was the reference category.

For the third part of the analysis (prediction of 8th-grade math course) the following school-level variables were included: school average SES, minority composition, sector (public or private), and location (urban, suburban, or rural).

Results

Table 1 presents the descriptive statistics for the variables included in the analyses. The sample was composed of 14% Black students, 12% Hispanic students, 5% Asian students, and 6% Other Races (Pacific Islanders and Native Americans). About half of the sample was male. With regard to family structure, 67% grew up with two married biological parents, 20% were raised in a single-parent family, and 13% were raised in other family structure (adoptive parents, remarried parents). Forty four percent of students were taking Algebra I or above.

Average math scores were as follows: 61.26 (SD=18.08) at the end of 1st grade, 98.72 (SD=24.71) at the end of 3rd grade, 123.69 (SD=24.79) at the end of 5th grade, and 142.22 (SD=22.01) at the end of 8th grade. Strong factor loadings for the three components of school readiness—math and reading scores, and approaches to learning in the fall of kindergarten—show that the construct of school readiness is well specified by these variables.

Table 1
Descriptive statistics

		Mean	SD
SES		.07	.79
Male		.51	.5
Black		.14	.35
Hispanic		.12	.33
Asian		.04	.21
Other race		.06	.24
Single parent		.20	.4
Other family structure		.13	.34
Number of siblings		1.49	1.11
School readiness			
	Math score at kindergarten	27.02	9.17
	Reading score at kindergarten	35.75	10.24
	Approaches to learning at kindergarten	3.03	.66
Math score at 1st grade		61.26	18.09
Math score at 3rd grade		98.72	24.71
Math score at 5th grade		123.69	24.79
Math score at 8th grade		142.22	22.01
Algebra I or above		.44	.50

N=12,256

Table 2 exhibits the three components of school readiness by race/ethnicity and gender. White and Asian students started kindergarten with higher math and reading scores and higher approaches to learning than did Black, Hispanic, and students of other races. Boys outperformed girls in math; the situation was reversed for reading.

Table 2
School readiness by race/ethnicity and gender

	Math	Reading	Approaches to learning
White	28.08	36.46	3.03
Black	22.47	32.43	2.78
Hispanic	21.82	32.43	2.87
Asian	29.41	39.39	3.08
Other race	23.93	33.02	2.88
Male	26.01	34.60	2.83
Female	25.79	35.84	3.10
Total sample	25.91	35.21	2.96

The relationship between school readiness and subsequent math achievement

Table 3 presents the regression analyses predicting students' math achievement at the end of the 1st, 3rd, 5th, and 8th grades from school readiness. Consistent with previous studies, students from higher-SES families had higher math scores at the end of each year, and this association was becoming larger as students proceeded through the grades. Males also scored consistently higher than females from 1st through 8th grade. In addition, a consistent disadvantage was indicated for Black and other race students compared to White students throughout the school years, whereas Hispanic students showed lower math achievement only at the end of 1st grade. In the case of Asian children, although they showed lower math scores at the end of 1st grade and no difference for 3rd grade, they scored higher than White children at the end of the 5th and 8th grades. Students growing up in other than two married biological parents' family structure had lower math scores. Students' school readiness at the start of kindergarten was positively and significantly associated with their later math achievement for every tested year, suggesting that the better prepared students hold a substantial advantage in math achievement from 1st through 8th grades. Specifically, early math score and approaches to learning were consistently associated with higher math score at each tested grade. Early reading score had a significant positive association with subsequent math scores only up to 3rd grade.

Table 3

Prediction of the end of 1st, 3rd, 5th and 8th grade math achievement by school readiness and student background characteristics

	1st grade	3rd grade	5th grade	8th grade
SES	1.728** (.168)	3.838** (.247)	4.72** (.279)	4.744** (.273)
Male	2.537** (.227)	5.729** (.335)	6.087** (.391)	2.861** (.394)
Black	-.465** (.318)	-8.927** (.549)	10.481** (.724)	-9.856** (.785)
Hispanic	-.898** (.345)	-.543 (.537)	.462 (.627)	.167 (.655)
Asian	-1.33* (.556)	.697 (.825)	3.758** (.862)	4.074** (.919)
Other race	-2.727** (.447)	-4.136** (.717)	-3.966** (.893)	-3.870** (.950)
Single parent	.072 (.297)	-.424 (.475)	-1.685** (.580)	-2.905** (.610)
Other family structure	-1.371* (.554)	-4.355** (.929)	-5.042** (1.166)	-6.255** (1.287)
Number of siblings	.265** (.096)	-.342* (.146)	-.748** (.182)	-.302 (.186)
Math K	1.145** (.024)	1.349** (.033)	1.160** (.035)	.851** (.032)
Reading K	.08** (.083)	.083** (.023)	.047 (.026)	.050 (.026)
Approaches to learning K	3.104** (.189)	4.872** (.287)	5.383** (.347)	4.22** (.355)

Note. Standard errors in parentheses
*p< .05; **p<.01

The impact of school readiness on math learning growth rate

Table 4 Model 1 presents analysis of the impact of school readiness on students' math learning growth rate from 1st through 8th grade. As shown in Model 1, students from higher-SES families demonstrated a faster math learning growth rate. Males did not have a faster math growth rate than female students, although they ended up with higher math scores at the end of every tested grade (as shown in Table 3). Black students had slower learning growth than White students; Hispanics did not differ from Whites; and Asian students had steeper growth relative to White students. Students growing up with single parents showed lower math score gains. Similarly, a larger number of siblings was negatively associated with math learning growth.

The relationship between school readiness and math learning growth rate showed a somewhat different pattern of influence compared to the analyses of school readiness and math scores at the end of each grade as shown in Table 3. Specifically, students who had higher early math score tended to show a lower rate of math growth, although they maintained higher math achievement at the end of each year. This finding is consistent with studies that reported a "ceiling effect": because possible regression to the mean and instructional opportunities are mostly targeted to the average level at every given grade, students who start higher have to slow down, thereby limiting the growth of the most advanced students. Early reading score had no significant association with math growth; stronger approaches to learning in kindergarten were associated with a steeper math growth between 1st and 8th grade.

Table 4

Prediction of student's math learning growth from 1st thru 8th grade, and taking Algebra I or higher by the end of 8th, by school readiness and background characteristics

	Model 1 Math growth	Model 2 Algebra I
SES	.418** (.036)	1.584** (.069)
Male	-.047 (.051)	.922 (.080)
Black	-.641** (.094)	-.731* (.159)
Hispanic	.131 (.082)	1.288 (.133)
Asian	.769** (.121)	2.863** (.245)
Other race	-.167 (.115)	-.947 (.172)
Single parent	-.381** (.075)	-.787* (.108)
Other family structure	-.657 (.156)	-.630* (.206)
Number of siblings	-.075** (.024)	-.975 (.035)
Math, K	-.048** (.003)	1.063** (.007)
Reading, K	-.004 (.003)	1.013* (.007)
Approaches to learning, K	.150** (.044)	1.477** (.070)

Note. Standard errors in parentheses. *$p< .05$; **$p<.01$
Model 1 presents coefficients from a growth curve model
Model 2 presents coefficients from a multi-level logistic regression

After the main effect of school readiness was examined, we looked at whether these effects vary for any particular group of students. Table 5 presents the interactions between school readiness and SES, gender, and race/ethnicity. The analysis is based on Model 1 in Table 4. For the concise and easy interpretation we used factor score for school readiness instead of three separate measures. Factor loadings for math, reading and approaches to learning in kindergarten were .896, .870, and .672 respectively. The negative significant interaction between school readiness and SES suggests that students from a lower SES background will significantly benefit from improved school readiness in terms of their math achievement growth. Further, a negative interaction effect between males and school readiness suggests that boys' consistent math advantage over girls is a function of their beginning school knowledge. Conversely, if girls' beginning math knowledge can be improved, their math growth rate will increase. The interaction effects between school readiness and race/ethnicity indicate that Black, Hispanic, and other races students' math learning growth can be improved by enhancing the level of their school readiness.

Table 5
The interaction coefficients between school readiness and students' SES, gender, and race/ethnicity

	Model 1	Model 2	Model 3
Readiness*SES	-.191** (.051)		
Readiness*Male		-.585** (.105)	
Readiness*Black			1.067** (.162)
Readiness*Hispanic			.875** (.189)
Readiness*Asian			.346 (.208)
Readiness*Other race			.834** (.227)

Note. For the concise and easy interpretation we used factor score for school readiness instead of three separate measures. Factor loadings for math, reading and approaches to learning in kindergarten were .896, .870, and .672 respectively.

The impact of school readiness on taking Algebra I and above

Table 4 Model 2 shows the analysis predicting taking Algebra I and above in 8th grade. Students from higher-SES families and Asian students were more likely to take Algebra I or higher in 8th grade, whereas Black students and those raised in anything other than two married, biological parents households were less likely to take Algebra I by the end of 8th grade. All three components of school readiness showed a significant positive association with a student's likelihood to enroll in Algebra I or higher. That is, higher math score, reading score, and approaches to learning in the fall of kindergarten were all associated with a higher odds of the student taking Algebra I or higher in 8th grade. We did not find any significant interaction effects between school readiness and student gender, race/ethnicity, and family SES. Thus, school readiness appears to equally affect the likelihood of taking an advanced math class in 8th grade for all students.

No school-level variables (school SES, minority composition, school sector and location) showed a significant relationship with advanced math course-taking. Thus, our findings regarding the end of middle school math course-taking, in particular the lack of variation by school sector, differ from findings regarding high school math trajectories. For instance, using the Education Longitudinal Study (ELS) data Carbonaro and Covay (2010) reported that Catholic school students are more likely to enjoy more academic math courses than public school students. Unfortunately, the ECLS-K study does not plan to continue data collection beyond 8th grade, so that it will not be possible to determine whether these differences exist at a high school level.

Discussion

We employed a large nationally representative data set for for the U.S. elementary school students, the Early Childhood Longitudinal Study – Kindergarten Cohort (ECLS-K), including the most recently available 8th-grade wave of data, which is the last time point preceding high school, to investigate how school readiness (measured at the beginning of kindergarten) affects students' mathematics learning through the end of middle school. Specifically, the study had three main objectives:

a) to estimate growth in students' mathematics achievement during elementary and middle school years as a function of school readiness; b) to examine mathematics courses taken in the 8th grade as a function of school readiness net of other student- and school-related factors; and c) to examine whether these relationships vary for different groups of students, defined by their gender, race/ethnicity, and family socioeconomic status.

We found that school readiness exhibited a strong positive relationship with math scores at the end of each tested grade. Thus, our overall findings suggest that those students who entered kindergarten readier for school had a consistent advantage in terms of subsequent math achievement. However, a different pattern has been detected with respect to mathematics achievement rate growth. Students who entered kindergarten with higher math score tended to exhibit lower rates of math growth over the years. We also examined the interaction terms between school readiness and SES, gender, and race/ethnicity. We found that for students from lower-SES backgrounds and for minority students, improved school readiness pays off in faster growth in math achievement.

Our findings support both arguments from previous studies: students' academic achievement is consistent over the years (on average, students who experience difficulties in early years continue to fall behind later on), but at the same time most advantaged students who start school with particularly strong skills may experience a ceiling effect. Because students whose math learning growth rates slow down still find themselves at the higher end of achievement distribution at the end of each tested year, it seems crucially important to focus on school readiness skills, particularly for those students at risk for underachievement. The U.S. educational system, as well as many other educational systems in the Western World, struggles to find a balance between providing equal opportunities to all students while cultivating excellence. A tension between these two goals often results in a struggle for educational resources (human resources, as well as financial and time allocation). A great effort is being exerted within the academic and policy communities to disentangle the plague of underachievement and its intertwined relationship with the socio-economic disadvantage of struggling students. While this problem is far from being resolved, perhaps future studies should also focus in greater detail on learning trajectories and experiences of the most advanced, including gifted students.

Further, we found that school readiness had a strong positive and significant association with the likelihood that a student has taken Algebra I or above in 8th grade. No significant interaction effects were found between school readiness and student gender, race/ethnicity, and family SES for 8th-grade math class. Thus, school readiness appears to equally and positively affect the likelihood of taking advanced math in 8th grade for all students, highlighting the universal importance of school readiness.

Generally, the estimation that 39% of students are enrolled in advanced math classes at the end of the 8th grade (U.S. DoE, 2010) illustrates a steady trend in U.S. education towards more rigorous math curricula. Only 16% of all U.S. 13-year olds were enrolled in algebra in 1986, 22% in 1999, and 29% in 2004 (U.S. DoE, 2010, p. 1). Such a significant increase is clearly a result of an educational policy designed to encourage students to take more advanced mathematics classes both in middle and high school . Although these policies are universal, our study reveals that not all students equally benefit from them. Our findings show that low-SES students and Black students, as well as students who grow up in other than two married biological parents' family structures are significantly less likely to be enrolled in advanced math courses at the end of middle school. Our finding that school readiness has a strong positive effect on the likelihood of taking Algebra I eight years later highlights the necessity of a more concerted focus on children's school preparation during the pre-school years. Because the findings show that Black and Hispanic students, as well as low-SES students, suffer from low levels of preparation at the school entry, the focus of the policy should be on these students. The encouraging finding, however, is that Hispanic students' math achievement difference from Whites lost its significance at 3rd grade and above. Further, Hispanic students did not differ from Whites in math growth and in terms of likelihood of taking Algebra I or above. It is beyond the scope of the current study to look at specific policies and programs that target minority students or students at risk for underachievement and the effects of these efforts on students' performance. It is a fruitful venue for future research to supplement our quantitative analysis with qualitative and policy studies to shed further light on these issues.

Taken together, our findings inform policy makers about the effects of school readiness on mathematics achievement at the end of middle school. This information may be used in creating interventions targeting students at risk of underachievement. It is important to note that our study does not enable determination of a causal relationship between school readiness and subsequent mathematics achievement and course selection, but our findings provide insights into the relationships between school readiness and later outcomes for different groups of children, thus suggesting where interventions that can be studied experimentally might be most effective (Schneider et al., 2007, p. 95). Furthermore, a longitudinal analysis of a large-scale, nationally representative data set allows statistical control for a variety of children- and school-related factors, which should help reduce bias in the estimates. In particular, the time lag of almost nine years between the measures of school readiness and the end of middle school achievement provides a basis for suggestive causal relationships and helps to reduce selection bias. Thus, our study maps the math growth trajectory from kindergarten to 8th grade based on students' school readiness, which is a necessary first step that lays the foundation for more rigorous future research that will address causality, such as propensity score modeling, to account for differences in mathematics achievement trajectories by individual-, family-, and school-related factors.

References

Alexander, K., Entwisle, D., & Horsey, C. (1997). From first grade forward: Early foundation of high school dropout. *Sociology of Education, 70* (April), 87–107.

Aunola, K., Leskinen, E., Lerkkanen, M.K., & Nurmi, J.E. (2004). Developmental dynamics of math performance from preschool to grade 2. *Journal of Educational Psychology, 96*(4), 699–713.

Ayalon, H. (2002). Mathematics and sciences course taking among Arab students in Israel: A case of unexpected gender equality. *Educational Evaluation and Policy Analysis, 24*(1), 63–80.

Bast, J., & Reitsma, P. (1997). Matthew effects in reading: A comparison of latent growth curve models and simplex models with structured means. *Multivariate Behavioral Research, 32*, 135–167.

Bloom, B. S. (1976). *Human characteristics and school learning*. New York: McGraw-Hill.

Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to- one tutoring. *Educational Researcher, 13*(6), 4–16.

Bodovski, K., & Farkas, G. (2007) Mathematics growth in early elementary school: The roles of beginning knowledge, student engagement and instruction. *The Elementary School Journal, 108*(2), 115–130.

Bodovski, K., & M-J. Youn. (2011). The long term effects of early acquired skills and behaviors on young children's achievement in literacy and mathematics. *Journal of Early Childhood Research*, *9*(1), 4-19.

Brophy, J. E. (1982) *Fostering students learning and motivation in the elementary school classroom. Occasional Paper no. 51*. East Lansing: Institute for Research on Teaching.

Brown, B. W., & Saks, D. H. (1986). Measuring the effects of instructional time on student learning: Evidence from the beginning teacher evaluation study. *American Journal of Education, 94*(4), 480–500.

Carbonaro, W., & Covay, E. (2010). School sector and student achievement in the era of standard based reforms. *Sociology of Education, 83*(2), 160–182.

Downey, D., von Hippel, P. T., & Broch, B. A. (2004). Are schools the great equalizer? Cognitive inequality during the summer months and the school year. *American Sociological Review, 69*, 613–635.

Duncan, G. J., & Magnuson, K.A. (2005). Can family socioeconomic resources account for racial and ethnic test score gaps? *The Future of Children, 15*(1), 35–54.

Duncan, G. J., Claessens A., Huston A.C., Pagani, L., Engel M., Sexton, H., Dowsett C.J., K. A. Magnuson, Klebanov P., Feinstein L., Brooks-Gunn J., Duckworth K., & Japel, C. (2007). School Readiness and Later Achievement. *Developmental Psychology, 43*(6), 1428–1446.

Duran, B. J., & Weffer R. (1992). Immigrants' aspirations, high school process, and academic outcomes. *American Educational Research Journal, 29*(1), 163–181.

Entwisle, D. R., & Alexander, K. L. (1996). Family type and children's growth in reading and math over the primary grades. *Journal of Marriage and the Family, 58*, 341–155.

Farkas, G., & Hibel, J. (2008). Being unready for school: Factors affecting risk and resilience. In A. Booth & A. Crouter (Eds.), *Disparities in school readiness: How families contribute to transitions into school*. (pp. 3–30). New York: Erlbaum.

Finn, J. D., Gerber, S. B., & Wang, M. C. (2002). Course offerings, course requirements, and course taking in mathematics. *Journal of Curriculum and Supervision, 17*(4), 336–366.

Gamoran A., & Hannigan, E.C. (2000). Algebra for everyone? Benefits of college-preparatory mathematics for students with diverse abilities in early secondary school. *Educational Evaluation and Policy Analysis, 22*(3), 241–254.

Hallinan, M., & Kubitschek, W. (1999). Curriculum differentiation and high school achievement. *Social Psychology of Education, 3*(1–2), 41–62.

Hooper, S.R., Roberts, J. Sideris, J., Burchinal, M., & Zeisel. S. (2010). Longitudinal Predictors of Reading and Math Trajectories Through Middle School for African American Versus Caucasian Students Across Two Samples, *Developmental Psychology, 46*, 1018—1029.

Horn, L., & Bobbitt, L. (2000). *Mapping the road to college: First-generation students' math track, planning strategies, and context of support. statistical analysis report. postsecondary education descriptive analysis reports* (110 Numerical/Quantitative Data; 143 Reports: Research No. NCES-2000-153). Alexandria, VA:National Center for Education Statistics.

Kelly, S. (2009). The black-white gap in mathematics course taking. *Sociology of Education, 82*(1), 47–69.

Lee. V., & Frank, K. (1990). Students' characteristics that facilitate the transfer from two- year to four- year colleges. *Sociology of Education, 63*(3), 178–193.

Lucas, S. (1999). *Tracking inequality: Stratification and mobility in American high schools.* New York: Teachers College Press.

Ma, X. (2000). Does early acceleration of advanced students in mathematics pay off? An examination of mathematics participation in the senior grades. *Focus on Learning Problems in Mathematics, 22*(1), 68–79.

Matthews, M. S., & Farmer, J. L. (2008). Factors affecting the algebra I achievement of academically talented learners. *Journal of Advanced Academics, 19*(3), 472–501.

Ozturk, M. A., & Singh, K. (2006). Direct and indirect effects of socioeconomic status and previous mathematics achievement on high school advanced mathematics course taking. *Mathematics Educator, 16*(2), 25–34.

Phillips, L. M., Norris, S. P., Osmond, W. C., & Maynard, A. M. (2002). Relative reading achievement: A longitudinal study of 187 children from first through sixth grades. *Journal of Educational Psychology, 94*, 3–13.

Raudenbush, S., & Bryk, A. (2002). *Hierarchical linear models* (2nd ed.). Thousand Oaks, CA: Sage.

Ready, D., LoGerfo, L., Burkam, D., & Lee, V. (2005). Explaining girls' advantage in kindergarten literacy learning: Do classroom behaviors make a difference? *The Elementary School Journal, 106*, 10–37.

Reardon, S., & Galindo, C. (2009). The Hispanic-White achievement gap in math and reading in the elementary grades. *American Educational Research Journal, 46*(3), 853–891.

Riegle-Crumb, C. (2006). The path through math: Course sequences and academic performance at the intersection of race-ethnicity and gender. *American Journal of Education, 113*, 101–122.

Riegle-Crumb, C., & Grodsky, E. (2010). Racial-ethnic differences at the intersection of math course- taking and achievement. *Sociology of Education, 83*(3), 248–270.

Schiller, K. S., & Muller, C. (2003). Raising the bar and equity? Effects of state high school graduation requirements and accountability policies on students' mathematics course taking. *Educational Evaluation and Policy Analysis, 25*(3), 299–318.

Schneider, B., Swanson, C., & Riegle-Crumb, C. (1998). Opportunities for learning: Course sequences and positional advantages. *Social Psychology of Education, 2*(1), 25–53.

Schneider, B., Carnoy, M., Kilpatrick, J., Schmidt, W.H., & Shavelson, R.J. (2007). *Estimating causal effects: Using experimental and observational designs.* Washington, D.C.: American Educational Research Association.

Stevenson, D., Schiller K., & Schneider, B. (1993). *Sequences of opportunities for learning, Sociology of Education, 67*, 184–198.

Tach, L., & Farkas, G. (2006). Learning-related behaviors, cognitive skills, and ability grouping when schooling begins. *Social Science Research, 35*, 1048–1079.

Trusty, J. (2002). Effects of high school course-taking and other variables on choice of science and mathematics college majors. *Journal of Counseling & Development*, *80*(4), 464–474.

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk*, *12*(3), 243–270.

U.S. Department of Education. (2004). *User's Manual for the ECLS-K third grade public-use data file and Electronic Code Book* (NCES Publication No. 2004-001). Alexandria, VA:Educational Publication Center.

U.S. Department of Education. (2008). *First Findings from the Final Round of the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS–K)*. (Publication No. 2008-088). Alexandria, VA:Educational Publication Center.

U.S. Department of Education. (2010). *Eight-Grade Algebra: Findings from the Eights –Grade Round of the Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS–K)*. (National Center for Education Statistics. Publication No. 2010-016). Alexandria, VA:Educational Publication Center

Wang, J., & Goldschmidt, P. (2003). Importance of middle school mathematics on high school students' mathematics achievement. *Journal of Educational Research, 97*(1), 3–19.

Williamson, G.. L., Appelbaum, M., & Epanchin, A. (1991). Longitudinal analysis of academic achievement. *Journal of Educational Measurement, 28*, 61–76.

Xue, Y., & Meisels, S. J. (2004). Early literacy instruction and learning in kindergarten: Evidence from the Early Childhood Longitudinal Study—Kindergarten class of 1998–1999. *American Educational Research Journal, 41*, 191–229.

Katerina Bodovski is Assistant Professor of Educational Theory & Policy of the Department of Education Policy Studies at the Pennsylvania State University.

Min-Jong Youn is Graduate Student at the Pennsylvania State University.

Contact Address: Department of Education Policy Studies, The Pennsylvania State University 300 Rackley Building University Park, PA 16802. Email: kxb918@psu.edu