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The Impact of High School Mathematics and Science Course Graduation Requirements: School Structural, Academic, and Social Organizational Factors

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Background and Focus of Study

Every year about half of high school seniors graduate without the minimal requirements needed to apply to a four-year college (ACT Inc., 2010; Greene & Foster, 2003). To improve student college readiness while ensuring the opportunity to learn for all, lawmakers and school leaders have been working to increase high school course graduation requirements (CGRs), especially in mathematics and science (Smerdon & Borman, 2012; The Center for Public Education, & Change the Equation, 2013). The existing evidence on the effects of high school CGRs, however, is scarce due to the methodological challenges such as lack of reliable and consistent data, and isolating the CGR impact from potential confounding factors with non-experimental data. Few studies have attempted to address these challenges, yet the findings are inconsistent (e.g., Jacob, Dynarski, Frank, Schneider, 2016; Lillard & DeCicca, 2001; Plunk, Tate, Bierut, & Grucza, 2014).

This study contributes to the limited research on high school CGRs in several respects. First, building upon the literature on school effects and social stratification, this study formulates a theoretical framework and develops a series of school contextual hypotheses to test the main and differential effects of high school CGRs, which help interpret the seemingly mixed findings in prior studies (see Figure 1 for the conceptual framework). Second, in contrast to most previous studies that estimated the effects of CGRs by subject at the district or state level, this study classifies schools into different comparison and treatment groups, which consider the numbers of years of coursework required in both math and science. Defining the treatment of CGRs at the school level allows for examination of differential effects by school context. Finally, this study draws on a nationally representative sample of high school students, which yields greater generalizability.

Research Hypotheses

Given the policy goals of CGRs, this study first tests the hypothesis that CGRs promote academic excellence and equity by both improving student performance (*productivity hypothesis*) and reducing the gap between student groups as defined by academic ability, race/ethnicity, and socioeconomic status (*equality hypothesis*). This study also assesses whether and how schools differ in CGRs effects by testing the following hypotheses that CGRs affect student outcomes more positively in schools with (a) higher concentration of advantaged peers (*school structure hypothesis*), (b) greater academic/instructional capacity (*academic organization hypothesis*), and (c) stronger academic norms/climate (*social organization hypothesis*).

Data and Methods

This study analyzes the data from the High School Longitudinal Study of 2009 (HSLS:09) that provide the information on high school CGRs in several academic subjects at the school level and rich survey data on students, teachers, and schools. The analytic sample is limited to those respondents who were first-time ninth graders in fall 2009 and participated in both 2009 base-year and 2012 follow-up survey and with valid information on their high school CGRs. Given the current policy debates on CGRs are primarily focusing on whether to increase math and science CGRs from three years to four years, this study analyzes only the school samples with CGRs of: (a) three years of math and science (3M3S), (b) four years of math and three years of science (4M3S), and (c) four years of math and science (4M4S). The final sample includes 13,240 students from 695 schools. Table 1 presents descriptive statistics of key analysis variables whereas Appendix Table A1 reports descriptive statistics of all covariates.

This study first estimates the overall impact of high school math and science CGRs by employing ordinary least squares (OLS) regression models with state fixed effects that take the following form:

$$Y_{ict} = \beta_0 + \beta_1 4M3S_{ict_0} + \beta_2 4M4S_{ict_0} + \boldsymbol{STU_{ict_0}\Gamma_1'} + \boldsymbol{SCH_{ct_0}\Gamma_2'} + \mu_s + \varepsilon_{ict} \quad (1)$$

where Y_{ist} is the student outcomes for student *i* in school *c*. $4M3S_{ict_0}$ and $4M4S_{ict_0}$ are dummy variables denoting whether a student attended a school with CGRs of 4M3S and 4M4S (t_0; the omitted school group is 3M3S). $\boldsymbol{STU_{ict_0}}$ is a vector of student characteristics for student *i* in school *c* as measured in time t_0, whereas $\boldsymbol{SCH_{ct_0}}$ is a vector of school factors for school *c* as measured in time t_0. The OLS models include state fixed effects (μ_s) to control for unobserved time-invariant characteristics that may be unique for each state. ε_{ict} is assumed a zero mean normally distributed error term. When testing the equality hypothesis of CGRs equation (1) is re-estimated using subsamples of students restricted to a specific subgroup as defined by racial/ethnic, socioeconomic, and academic ability status. To explore whether and the extent to which the effects of CGRs are moderated by school factors, equation (1) is re-estimated separately by including interaction terms of the two dummy variables of interest, $4M3S_{ict_0}$ and $4M4S_{ict_0}$, with each of the school contextual variables, as reported in Table 1.

Results

The empirical findings show that (a) higher math CGRs had positive effect on student math cognitive improvement, and (b) higher CGRs both in math and science had no impact on student test scores yet decreased the likelihood of students attending a four-year college in the semester after high school senior year (See Table 2). The second set of key findings indicates that students who are multiracial, lowest- and highest-achieving benefited the most by enrolling in schools with higher math and science CGRs while high-middle SES students who attended higher math and science schools had significantly lower math scores and lower probability of enrolling in a four-year college (see Table 3). The third set of key findings identifies two key school moderators, advanced course offering and student engagement in school, could optimize the CGR effects (see Table 4).

This study adds to a growing body of evidence that high school CGRs could serve as a policy tool to improve student achievement by increasing opportunities to learn for traditionally underserved students. Yet policymakers and school leaders need to be aware of and to address the potential unintended negative consequences on certain student outcomes and for specific student subgroups. This study also emphasizes that identifying and studying the moderating role of school contextual factors can be useful to conceptually and empirically better understand the linkage between high school CGRs and student outcomes.

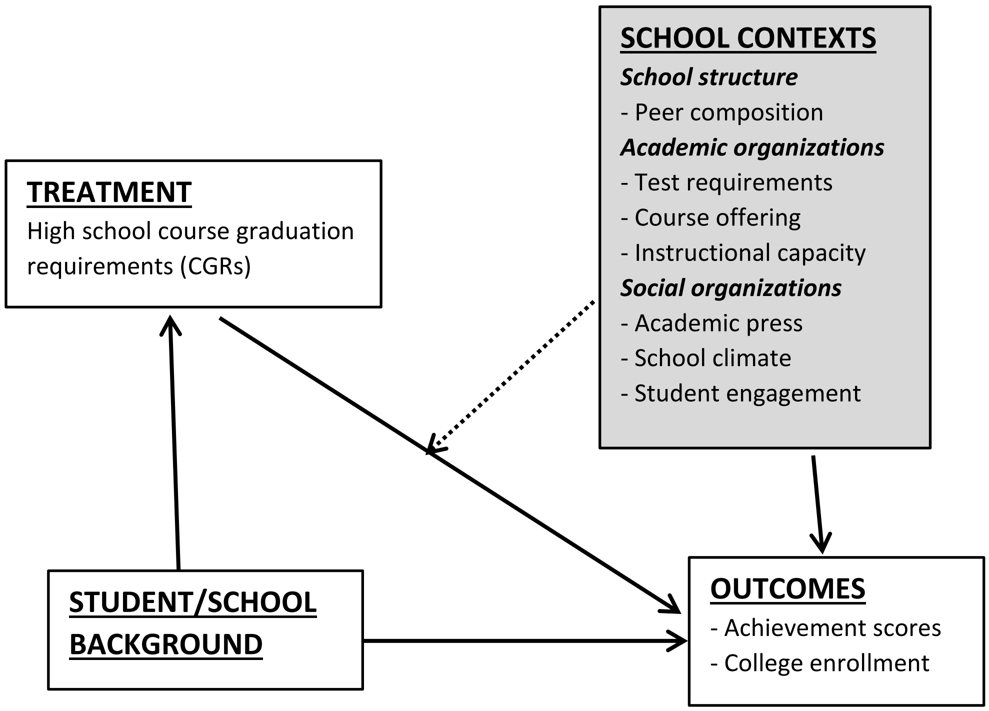

FIGURE 1. *The hypothesized relationship between the course graduation requirements (CGRs) and student outcomes, and the moderating role of school contextual factors.*

Table 1
Summary Statistics for Key Variables by High School Mathematics and Science Course Graduation Requirements

		High School Course Graduation Requirements		
	All	3M3S	4M3S	4M4S
Number of students	13,240	4,728	4,905	3,607
Number of schools	695	257	252	186
Race/ethnicity				
White	.598	.659	.627	.479
Black	.129	.102	.114	.184
Hispanic	.164	.129	.147	.232
Asian	.026	.030	.019	.027
Multirace	.074	.072	.076	.074
Other race	.010	.008	.017	.004
Socioeconomic status	.020	.087	-.011	-.040
	(.750)	(.747)	(.755)	(.744)
9th grade math test score	51.101	51.589	50.581	50.976
	(9.659)	(9.765)	(9.863)	(9.238)
School structural organizations				
% of poverty students	.367	.320	.397	.404
	(.243)	(.239)	(.245)	(.237)
% of minority students	.332	.281	.315	.424
	(.290)	(.292)	(.287)	(.269)
% of AP students	.152	.140	.137	.186
	(.126)	(.120)	(.108)	(.145)
School academic organizations				
Requiring a math competency test	.695	.659	.746	.688
Offering AP courses	.899	.898	.905	.896
Math/science teacher ratio	.244	.239	.243	.253
	(.051)	(.049)	(.051)	(.053)
School social organizations				
Academic press	-.037	-.060	-.040	.000
	(1.040)	(1.010)	(1.095)	(1.012)
School climate	-.432	-.469	-.557	-.218
	(.971)	(.923)	(1.003)	(.980)
Student engagement	-.051	-.055	-.178	.104
	(.958)	(.988)	(.900)	(.954)
Student Outcomes				
11th grade math test score	50.452	51.175	50.025	49.894
	(9.866)	(10.036)	(9.900)	(9.516)
Attending a 4-year college	.342	.383	.311	.318

Source. High School Longitudinal Study of 2009 (HSLS:09)
Note. 3M3S = 3 years of math and science; 4M3S = 4 years of math and 3 years of science; 4M4S = 4 years of math and science; AP = Advanced Placement. Sample is restricted to first-time ninth graders in fall 2009, whose schools has valid information on math and science course graduation requirements. Estimates are weighted using base-year student analytic weight (W1STUDENT). Standard deviations appear in the parentheses below means of continuous variables.

Table 2
Effects of High School Math and Science Course Graduation Requirements

	11th grade math test score		Attending a 4-year college	
HS Course graduation requirements				
(ref: 3 years of math and science; 3M3S)				
4 years of math, 3 years of science (4M3S)	0.601 *	(0.280)	-0.006	(0.018)
4 years of math and science (4M4S)	0.017	(0.347)	-0.054 *	(0.021)
Race/ethnicity (ref: white)				
Black	-0.617 *	(0.278)	-0.001	(0.020)
Hispanic	-0.336	(0.243)	-0.001	(0.017)
Asian	2.226 ***	(0.358)	0.066 **	(0.025)
Multirace	-0.238	(0.319)	-0.023	(0.019)
Other race	-1.605	(0.981)	0.044	(0.063)
Socioeconomic status	0.850 ***	(0.144)	0.125 ***	(0.009)
9th grade math test score	0.518 ***	(0.013)	0.009 ***	(0.001)
School structural organizations				
% of poverty students	-1.683 *	(0.656)	0.012	(0.042)
% of minority students	-0.898 †	(0.470)	0.009	(0.040)
% of AP students	-0.904	(0.785)	-0.036	(0.063)
School academic organizations				
Requiring a math competency test	0.217	(0.203)	-0.015	(0.013)
Offering AP courses	0.723 *	(0.291)	0.024	(0.017)
Math/science teacher ratio	3.763 †	(1.960)	0.231 *	(0.115)
School social organizations				
Academic press	0.221 **	(0.085)	0.015 **	(0.005)
School climate	0.001	(0.109)	0.007	(0.007)
Student engagement	-0.030	(0.133)	0.007	(0.008)
Number of students	13,240		10,509	
Number of schools	695		695	
R-squared	.607		.358	

Note. HS = high school; AP = Advanced Placement. All models estimated with state fixed effects. Models also include student and school covariates presented in Table A1. Standard errors clustered by school are reported in parentheses.
*** p<.001; ** p<.01; * p<.05; †p < .10.

Table 3

Effects of High School Course Graduation Requirements for Student Subgroups

Racial Subgroups	White	Black	Hispanic	Asian	Multirace
Panel A1: 11th Grade Math Test Score					
4 years of math, 3 years of science (4M3S)	0.636*	0.238	1.141 †	1.859 †	1.060
	(0.313)	(0.893)	(0.687)	(0.946)	(0.896)
4 years of math and science (4M4S)	0.245	-0.473	-0.603	-0.576	-0.534
	(0.372)	(1.073)	(0.799)	(1.138)	(1.082)
Number of students	7,822	1,257	1,918	1,006	1,113
Panel A2: Attending a Four-Year College					
4 years of math, 3 years of science (4M3S)	0.002	-0.111 †	0.015	0.120 †	0.142*
	(0.022)	(0.058)	(0.045)	(0.070)	(0.062)
4 years of math and science (4M4S)	-0.046 †	-0.085	-0.004	0.125	-0.077
	(0.028)	(0.069)	(0.055)	(0.083)	(0.072)
Number of students	6,289	960	1,475	826	866

Socioeconomic Subgroups	Lowest SES	Low-Middle SES	High-Middle SES	Highest SES
Panel B1: 11th Grade Math Test Score				
4 years of math, 3 years of science (4M3S)	0.626	0.709	0.448	0.991 *
	(0.527)	(0.547)	(0.447)	(0.436)
4 years of math and science (4M4S)	0.376	0.722	-1.158 *	0.495
	(0.727)	(0.717)	(0.524)	(0.537)
Number of students	3,316	3,304	3,310	3,310
Panel B2: Attending a Four-Year College				
4 years of math, 3 years of science (4M3S)	0.013	0.044	0.011	-0.022
	(0.027)	(0.031)	(0.037)	(0.033)
4 years of math and science (4M4S)	0.028	-0.030	-0.145 **	-0.009
	(0.040)	(0.042)	(0.047)	(0.042)
Number of students	2,437	2,503	2,615	2,954

Math Ability Subgroups	Lowest Ability	Low-Middle Ability	High-Middle Ability	Highest Ability
Panel C1: 11th Grade Math Test Score				
4 years of math, 3 years of science (4M3S)	1.495 **	-0.211	0.738	1.149 **
	(0.457)	(0.511)	(0.480)	(0.415)
4 years of math and science (4M4S)	1.023 †	-0.597	0.372	-0.803
	(0.617)	(0.610)	(0.504)	(0.602)
Number of students	3,310	3,310	3,310	3,310
Panel C2: Attending a Four-Year College				
4 years of math, 3 years of science (4M3S)	-0.015	-0.022	-0.006	0.068 †
	(0.026)	(0.034)	(0.035)	(0.035)
4 years of math and science (4M4S)	-0.042	-0.006	-0.089 *	-0.037
	(0.034)	(0.042)	(0.043)	(0.044)
Number of students	2,419	2,541	2,672	2,877

Note. Each cell in the table shows the estimate on the effect of high school course graduation requirement in math or science (comparison group: 3 years of math and science). All models estimated with state fixed effects. Models include student and school covariates presented in Table A1. Standard errors clustered by school are reported in parentheses.
*** p<.001; ** p<.01; * p<.05; †p < .10 (two-tailed test).

Table 4

Effects of High School Course Graduation Requirements by School Organizations

	11th Grade Math Test Score			Attending a Four-Year College		
Panel A: School Structural Organizations						
4 years of math, 3 years of science	0.408	0.437	0.436	-0.028	-0.015	-0.015
(4M3S)	(0.434)	(0.358)	(0.418)	(0.026)	(0.024)	(0.026)
4 years of math and science (4M4S)	0.191	0.449	0.154	-0.071 **	-0.069 *	-0.069 *
	(0.448)	(0.420)	(0.460)	(0.027)	(0.027)	(0.028)
% of poverty students	-1.930 *			-0.038		
	(0.850)			(0.059)		
% of poverty students x 4M3S	0.812			0.053		
	(0.990)			(0.056)		
% of poverty students x 4M4S	0.357			0.049		
	(0.869)			(0.056)		
% of minority students		-1.281 *			-0.012	
		(0.636)			(0.057)	
% of minority students x 4M3S		1.082			0.027	
		(0.894)			(0.055)	
% of minority students x 4M4S		-0.632			0.035	
		(0.804)			(0.054)	
% of AP students			-1.283			-0.162
			(1.456)			(0.109)
% of AP students x 4M3S			2.327			0.099
			(2.019)			(0.123)
% of AP students x 4M4S			1.087			0.043
			(1.951)			(0.121)
Number of students	12,202	9,715	11,716	7,495	12,239	9,735
Panel B: School Academic Organizations						
4 years of math, 3 years of science	0.608	-0.625	-0.226	-0.008	0.011	0.098
(4M3S)	(0.444)	(0.584)	(1.167)	(0.027)	(0.038)	(0.068)
4 years of math and science (4M4S)	0.114	-0.719	-1.447	-0.034	-0.063	-0.022
	(0.545)	(0.674)	(1.102)	(0.032)	(0.039)	(0.066)
Requiring a math test	0.181			-0.000		
	(0.343)			(0.022)		
Requiring a math test x 4M3S	0.050			-0.003		
	(0.474)			(0.029)		
Requiring a math test x 4M4S	0.011			-0.021		
	(0.492)			(0.031)		
Offering AP courses		-0.009			0.033	
		(0.383)			(0.026)	
Offering AP courses x 4M3S		1.441 **			-0.024	
		(0.554)			(0.037)	
Offering AP courses x 4M4S		1.037			0.007	
		(0.654)			(0.037)	
Math/science teacher ratio			0.046			0.038 *
			(0.302)			(0.019)
Math/science teacher ratio x 4M3S			0.415			-0.038
			(0.450)			(0.026)
Math/science teacher ratio x 4M4S			0.699 †			-0.010
			(0.417)			(0.026)
Number of students	12,154	11,571	11,617	9,640	9,187	9,227

Note. All models estimated with state fixed effects. Models include student and school covariates presented in Table A1. Standard errors clustered by school are reported in parentheses.
*** p<.001; ** p<.01; * p<.05; †p < .10 (two-tailed test).

Table 4 (continued)

Effects of High School Course Graduation Requirements by School Organizations

	11th Grade Math Test Score			Attending a Four-Year College		
Panel C: School Social Organizations						
4 years of math, 3 years of science (4M3S)	0.788 **	0.596 †	0.625 *	-0.005	-0.019	-0.025
	(0.282)	(0.318)	(0.308)	(0.019)	(0.020)	(0.019)
4 years of math and science (4M4S)	0.217	0.265	0.220	-0.032	-0.071 **	-0.057 *
	(0.376)	(0.382)	(0.371)	(0.025)	(0.025)	(0.024)
Academic press	0.232			0.018 †		
	(0.149)			(0.010)		
Academic press x 4M3S	0.035			0.000		
	(0.203)			(0.013)		
Academic press x 4M4S	0.066			-0.022		
	(0.225)			(0.016)		
School climate		-0.161			0.001	
		(0.176)			(0.011)	
School climate x 4M3S		0.061			-0.003	
		(0.202)			(0.012)	
School climate x 4M4S		0.270			0.007	
		(0.218)			(0.014)	
Student engagement			-0.326 †			0.012
			(0.188)			(0.012)
Student engagement x 4M3S			0.250			-0.013
			(0.229)			(0.014)
Student engagement x 4M4S			0.460 *			-0.002
			(0.206)			(0.015)
Number of students	11,771	10,734	11,055	9,332	8,532	8,788

Note. All models estimated with state fixed effects. Models include student and school covariates presented in Table A1. Standard errors clustered by school are reported in parentheses.
*** p<.001; ** p<.01; * p<.05; †p < .10 (two-tailed test).

Appendix

Table A1

Descriptive Statistics of Covariates (n=13,240)

Variables	Mean	Standard Deviation	Range
Student characteristics			
Female	.507	.500	0-1
White	.598	.490	0-1
Black	.129	.335	0-1
Hispanic	.164	.370	0-1
Asian	.026	.158	0-1
Multirace	.074	.261	0-1
Other race	.010	.099	0-1
Socioeconomic status (composite)	.020	.750	-1.82-2.88
Family structure			
Intact family	.582	.493	0-1
Two parents/guardians	.178	.383	0-1
Single parent	.222	.415	0-1
Other family structure	.018	.131	0-1
Had a parent worked in STEM fields	.226	.418	0-1
Career aspiration in STEM fields	.336	.472	0-1
Education aspiration			
High school or less	.119	.324	0-1
Associate’s degree	.068	.252	0-1
Bachelor’s degree	.174	.379	0-1
Advanced degree	.434	.496	0-1
Don’t know	.205	.403	0-1
9^{th} grade math test score	51.101	9.659	24.10-82.19
Highest math course taken in 8^{th} grade			
Math 8	.264	.441	0-1
Pre-algebra	.339	.474	0-1
Algebra I	.300	.458	0-1
Algebra II	.055	.229	0-1
Other math	.041	.199	0-1
Number of years of math courses expected to take in HS			
1 or 2 years	.085	.279	0-1
3 years	.245	.430	0-1
4 years	.669	.470	0-1
Knowing the importance of math for applying college	.553	.497	0-1
Knowing the importance of math in college education	.513	.500	0-1
Math identity (composite)	.057	1.002	-1.73-1.76
Math utility (composite)	.003	.996	-3.51-1.31
Math self-efficacy (composite)	.049	.980	-2.92-1.62
Interest in math course (composite)	.054	.996	-2.46-2.08
Science identity (composite)	.043	1.000	-1.57-2.15
Science utility (composite)	.007	.996	-3.10-1.69
Science self-efficacy (composite)	.027	.989	-2.91-1.83
Interest in science course (composite)	.030	.990	-2.59-2.03
Academic commitment (composite)	.014	.988	-4.50-1.60
Sense of school belonging	.071	.975	-4.35-1.59
School engagement (composite)	.078	.958	-3.38-1.39
Hours/week spent on studying/homework	3.158	2.158	.5-16.5

Source. High School Longitudinal Study of 2009 (HSLS:09)
Note. n = sample size; STEM = Science, technology, engineering, and mathematics; HS = high school. Sample is restricted to first-time ninth graders in fall 2009, whose schools has valid information on math and science course graduation requirements. Estimates are weighted using base-year student analytic weight (W1STUDENT).

Table A1 (continued)

Descriptive Statistics of Covariates (n=13,240)

Variables	Mean	Standard Deviation	Range
School structural organizations			
% of poverty students	.367	.243	0-1
% of minority students	.332	.290	0-1
% of AP students	.152	.126	0-1
School academic organizations			
Requiring a math competency test	.695	.460	0-1
Offering AP courses	.899	.301	0-1
Math/science teacher ratio	.244	.051	0-.45
School social organizations			
Academic press	-.037	1.040	-6.02-1.43
School climate	-.432	.971	-4.22-1.97
Student engagement	-.051	.958	-2.92-1.81
Other school covariates			
School sector			
Public	.911	.284	0-1
Catholic	.052	.221	0-1
Other private	.037	.190	0-1
Geographic region			
Northeast	.188	.391	0-1
Midwest	.241	.428	0-1
South	.096	.295	0-1
West	.475	.499	0-1
Urbanicity			
City	.244	.430	0-1
Suburb	.344	.475	0-1
Town	.134	.341	0-1
Rural	.277	.447	0-1
Grade span			
PK-12	.054	.225	0-1
6-12	.055	.227	0-1
9-12	.892	.311	0-1
Single-sex school	.023	.151	0-1
Magnet school	.001	.034	0-1
Charter school	.030	.170	0-1
Participated in school choice program	.285	.451	0-1
Average instruction hours per day	6.127	.601	3.8-8
Adequate Yearly Progress (AYP) status			
Met AYP	.695	.460	0-1
Year 1 school improvement	.101	.301	0-1
Year 2 school improvement	.110	.313	0-1
Year 3-5 school improvement	.094	.291	0-1
% of English language learner students	.044	.079	0-.70
% of special education students	.126	.069	0-.45
% of students enrolled in an alternative program	.024	.033	0-.30
% of students enrolled in a dropout prevention program	.016	.035	0-.40
Average daily attendance percentage for HS students	.939	.027	.80-.99

Source. High School Longitudinal Study of 2009 (HSLS:09)

Note. n = sample size; STEM = Science, technology, engineering, and mathematics; HS = high school. Sample is restricted to first-time ninth graders in fall 2009, whose schools has valid information on math and science course graduation requirements. Estimates are weighted using base-year student analytic weight (W1STUDENT).

Table A1 (continued)

Descriptive Statistics of Covariates (n=13,240)

Variables	Mean	Standard Deviation	Range
% of 9th graders enrolled in prior year returned	.916	.141	0-1
% of 9th graders who are repeating 9th grade	.049	.068	0-.72
% of graduates attending 2-year colleges	.265	.152	0-1
% of graduates attending 4-year colleges	.499	.238	0-1
Total number of teachers	86.78	49.32	4-260
% of full time teachers	.953	.067	.47-1
% of HS teachers absent on an average day	.034	.025	0-.22
Offering advanced math courses	.942	.234	0-1
Offering alternative programs	.331	.471	0-1
Offering dropout prevention programs	.342	.474	0-1
Having formal GED test preparation program	.149	.356	0-1
Organizing math/science extracurricular programs (composite)	.108	.948	-2.02-2.14
Program encouraging underrepresented students in STEM	.293	.455	0-1
Program informing parents about STEM higher ed/careers	.412	.492	0-1
School counseling program's most emphasized goal			0-1
Help students prepare for postsecondary schooling	.503	.500	0-1
Help students improve achievement in HS	.324	.468	0-1
Other goal (e.g., preparing for work, personal growth)	.174	.379	0-1
Having counselor designated for college-going	.617	.486	0-1
Average caseload for school's counselors	359.515	125.903	4-950
Students are required to have an education plan	.810	.392	0-1
Program to encourage student not considering college to do so	.764	.424	0-1
Consulting with college officers about qualifications	.961	.194	0-1
Organizing student visits to colleges	.702	.457	0-1
Offering Upward Bound/GEAR UP/AVID/MESA	.481	.500	0-1
Holding info session on college transitions for students/parents	.950	.219	0-1
Assisting students with finding financial aid for college	.960	.196	0-1
Providing opportunities for dual/concurrent enrollment	.916	.278	0-1
Taking other steps to assist with HS to college transition	.367	.482	0-1

Source. High School Longitudinal Study of 2009 (HSLS:09)

Note. n = sample size; STEM = Science, technology, engineering, and mathematics; HS = high school. Sample is restricted to first-time ninth graders in fall 2009, whose schools has valid information on math and science course graduation requirements. Estimates are weighted using base-year student analytic weight (W1STUDENT).