



Factors Associated with Grade 9 Math Success in Denver Public Schools

Appendix A. Methods

Appendix B. Supporting analyses

Appendix C. Other analyses

See the [Institute of Education Sciences website](#) for the full report.

Appendix A. Methods

This appendix describes the study’s data source, measures, sample, and analytic methods.

Data source

This study used student-, school-, and teacher-level administrative data from Denver Public Schools (DPS). DPS provided de-identified data for all students enrolled in grades 6–9 during school years 2014/15–2022/23 (table A1). DPS also provided school-level data for all schools serving students in grades 6–9 and de-identified teacher-level data for schools serving grades 6–9 for the same years (teacher data were then aggregated to the school level). Teacher data were unavailable for charter schools. The study team linked the student, teacher, and school datasets using unique school codes and linked students across school years using unique student identifiers. Students were not matched to their exact teachers; rather, teachers were matched to the schools that students attended.

Table A1. Study school years by grade 9 cohort, 2014/15–2022/23

Cohort	Grade 9 year	Grade 8 year	Grade 7 year	Grade 6 year
1	2017/18	2016/17	2015/16	2014/15
2	2018/19	2017/18	2016/17	2015/16
3	2020/21	2019/20	2018/19	2017/18
4	2021/22	2020/21	2019/20	2018/19
5	2022/23	2021/22	2020/21	2019/20

Note: Cohort 2019/20 was excluded from analyses because of significant disruptions from the Covid-19 pandemic in grade 9. Students were assigned a cohort based on the first time they entered grade 9.

Source: Authors’ compilation.

Measures

This section describes the measures used in the study, including information on data cleaning and recoding, if applicable.

Outcome measures

Primary outcome. This study examined the association between student characteristics and experiences and grade 9 math success. The study team consulted with DPS on the best way to measure grade 9 math success. Based on the DPS definition, the primary measure of grade 9 math success applied in this study is passing a student's main math course during grade 9. The key findings in the main report focus on this outcome. This section describes how the study team constructed this primary outcome.

Primary outcome: passing grade 9 math course.

Secondary outcome: meeting proficiency benchmark on Preliminary SAT 9 math exam.

Because DPS schools have considerable autonomy and use a variety of approaches to track course passage and credit accumulation, constructing the primary outcome required extensive data cleaning. DPS staff provided feedback and input on this process to ensure that the primary outcome reflected district course-taking and credit accumulation priorities.

To construct the primary outcome, the study team first identified each student's main grade 9 math course (some students take multiple math courses) and then determined whether the student passed the course.

Identifying main grade 9 math course. Many DPS students take multiple math courses during grade 9, and math course codes vary by school. About a quarter of the sample took multiple math courses during grade 9, most of which were an intervention math course. Across years and schools, courses with the same title (such as Integrated Math I) often had different course codes. The team recoded all courses with the same name so that they had the same course code. Some DPS schools have a math course that spans the entire year, whereas other schools split a single math course into two semester-long courses. The study team assigned both semesters of the same course to a single course code. For example, for Integrated Math I (the grade 9 math course taken by a majority of the sample), some schools have grade 9 students take a single Integrated Math I course for the entire year, and some schools split the course into two semester-long courses, Integrated Math I Semester I and Integrated Math I Semester II, each with its own course code in school records. The study team assigned all courses with the same root course name and level to the same course code because the district considers these to be the same full-year course. For example, Integrated Math I, Integrated Math I Semester I, and Integrated Math I Semester II would have the same course code, as would Algebra II, Algebra II Semester I, and Algebra II Semester II.

After standardizing course codes across years and schools, the study team selected the main math course for students using the following decision rules developed in consultation with DPS staff. DPS implemented its Integrated Math I, II, and III sequence in 2017/18. Prior to that, the district had an Algebra I, Geometry I, and Algebra II math course sequence. DPS confirmed that Integrated Math I should be the main math course for most grade 9 students in the study, though Algebra I could be some students' main math course in earlier years.

The following courses were prioritized as a student's main math course, based on DPS leadership's input:

- Integrated Math I.
- Algebra I.
- Math I.
- Geometry I.

If a student took two levels of the same course (for example, Algebra I and Algebra II), then the lower-level course was considered their main math course. All regression models control for the type of math course a student took as their main math course (see table A3 for distribution).

Determining a passing grade. Once the study team identified each student’s main math course, they determined passing grades. DPS does not report final course grades on report cards. Grades are reported by term. DPS schools vary in the number of terms per school year. For example, some schools have four terms (quarters) while others have three (trimesters) or two (semesters), and each term with a passing grade earns credits toward course completion. In general, if a student received a passing grade in all observed terms for their main grade 9 math course, then that student is classified as having succeeded in grade 9 math. The study defines passing a course this way because students need to accumulate 10 credits to pass a course, regardless of how many terms a course has. For example, if a school has a semester-based system and a student took Algebra I in terms 1 and 2, the student must pass the course in each term (earning 5 credits each) to earn the full 10 credits needed to pass the course as a whole. DPS provided the study team with term-level transcript data that included students’ raw grades. The study team used these data to determine whether students passed their course.

The study team did not have information on the number of terms each school used over time and could not infer this information from the data provided. Many students’ transcript data included nonsequential term numbers. For example, a student transcript might include grades for Integrated Math I in terms 1, 3, and 4. If this hypothetical student earned a passing grade in all three terms for which data were available, the study considers that student to have succeeded in grade 9 math. If this student earned at least one failing grade in these three terms, they did not accumulate all the credits needed to pass the course. For the students with nonsequential terms, one limitation of the study is that the study team does not know the course grade of students in the missing terms or whether nonsequential term designations represent data quality issues.¹

DPS schools also varied in their grading schemes. Some DPS high schools used A-F letter grades, while some used a 1-4 scale. DPS provided a crosswalk identifying the passing threshold for the primary grading scales their schools use.

Secondary outcome. The secondary outcome for this study is meeting or exceeding the grade-level proficiency benchmark on the Preliminary SAT 9 (PSAT 9) math exam.² This benchmark represents the math score students should meet or exceed to be considered on track for college and career readiness. DPS began administering the PSAT 9 to all grade 9 students as an alternative measure of math success, following legislation passed in Colorado in 2016 and 2017 that requires these assessments for grade 9 and 10 students (Colorado Department of Education, 2023). To construct this measure, the study team used publicly available proficiency benchmarks to transform raw scores into binary indicators. For findings on this secondary outcome, see appendix C.

Factors—measures of student characteristics and experiences

DPS provided the study team with a rich set of data on student characteristics and experiences. To decide which factors to include in regression models, the team prioritized experiences that DPS identified as high interest,

¹ The study defined its primary outcome based on all observed terms. Approximately a quarter of the sample had nonsequential term numbers. Among students who had complete term information, 65 percent were determined to have been successful in grade 9 math. Among students with nonsequential term numbers, 84 percent were determined to have been successful in grade 9 math. In consultation with DPS, the study chose to use this definition (passing math courses in all observed terms) to maximize the size of the study sample.

² The study also examined a tertiary outcome, passing the main grade 9 math course and meeting the grade-level proficiency benchmark on the PSAT 9. With the exception of minor differences in magnitudes, results were similar for the secondary and tertiary outcome measures. This is likely because almost all students (99 percent) who met the PSAT 9 benchmark passed their grade 9 math course. Less than half of students who passed their grade 9 math course achieved proficiency on the PSAT 9.

such as participation in summer programs or attending a school that hosts a newcomer center. The team also prioritized factors that prior research found to be associated with high school achievement. The team excluded factors that measure closely related constructs, such as indicators for language proficiency ratings, which are highly correlated with receiving multilingual learner services. The team also excluded variables with very little variation in the study sample, such as teachers having advanced certification (for example, 2 percent of sample teachers had national board certification). The student characteristics and experiences examined are in table A2.

Most factors have a middle school and a grade 9 version (for example, whether a middle school or high school employs an above-average percentage of male teachers), except for variables that were highly consistent over time (such as student sex or home language) and variables that apply only to middle school grades (such as meeting proficiency benchmarks on Colorado Measures of Academic Success [CMAS] standardized exams) or to grade 9 (such as taking Integrated Math I). Additionally, some grade 9 experiences that have a high chance of being influenced by middle school experiences have only a middle school version. These include all grade 9 academic supports, academic achievement, and school engagement factors; only the middle school versions of these variables are included in the main analysis for this report. Some grade 9 experiences are included in exploratory analyses in appendix C.

All student-level factors rely on student-level administrative data provided by DPS. Student-level middle school continuous variables (such as math course attendance rate) are the mean of that variable during grades 6-8 (or during whatever middle school grades the student attended in DPS schools). For example, the attendance rate of a student enrolled in DPS during grades 7 and 8 would be the average of their attendance rates in grades 7 and 8. Student-level middle school indicators (such as experiencing any suspension) are equal to 1 if that variable was equal to 1 during any middle school year. For example, if a student was suspended only in grade 7, the any suspension in middle school indicator would be equal to 1.

All school-level variables on the characteristics of students in a school were constructed using school-level administrative data provided by DPS. The study used measures such as average test scores and average attendance rate to capture aspects of school quality. These measures were used instead of state-level school performance ratings, which were not available for all study years due to the Covid-19 pandemic pause in ratings. The study linked school-level variables to individual student records using enrollment data. School-level “above-average” indicators were constructed using thresholds based on annual district averages (means) drawn from publicly available information from the Colorado Department of Education. An exception was the above-average attendance threshold, which was constructed using the DPS district average because state averages were unavailable. The study aggregated teacher-level data to the school level. School-level “above-average” indicators for teacher characteristics were constructed using annual thresholds based on the sample means.

School variables for grade 9 are based on the main school a student attended in the first school year in which they enrolled in grade 9. A student’s main grade 9 school is the school that they attended for the longest time during that school year. A student’s main middle school is the middle school that they attended for the longest time during grades 6-8.

School-level middle school continuous variables (such as student-teacher ratio) are the mean of that variable for the years during which a student was enrolled in their main middle school. Middle school indicators (such as attending an innovation school) are equal to 1 for a given student if that indicator was ever equal to 1 during a year that student was enrolled. For example, if a student attended an innovation school for grades 6 and 7 but transferred to a different school type for grade 8, the variable for the middle school innovation school indicator would be set to 1 because that student’s main school was an innovation school at some point during middle school.

Table A2. Factor variable definitions

Factor	Definition	Grade 9 version	Middle school version
Student characteristics (all binary indicators)			
Male	Identified as male	X	
Female	Identified as female	X	
White	Non-Hispanic, White	X	
Black	Non-Hispanic, Black	X	
Hispanic	Hispanic	X	
Other race/ethnicity	American Indian or Alaska Native, Asian, multiple races, or Native Hawaiian or Other Pacific Islander	X	
National School Lunch program	Eligible for the National School Lunch Program	X	
Home language: English	English is their primary language at home	X	
Home language: Spanish	Spanish is their primary language at home	X	
Home language: Other	Language other than English or Spanish is their primary language at home	X	
Newcomer	A student new to the United States at any point during grades 6-9 with a history of limited or interrupted education and with minimal literacy skills in both their home language and English; Denver Public Schools (DPS) defines “new” as being enrolled in a U.S. school for fewer than two semesters	X	
Student experiences			
<i>Received academic supports in middle school^a</i> (all binary indicators)			
504 plan	Ever had a 504 plan in middle school. A 504 plan is a written accommodation plan that ensures that students with disabilities have equal access to education programs, services, and activities		X
Gifted program	Ever identified as gifted or talented in middle school and participated in the programming for students whose aptitude or competence in abilities, talents, and potential for accomplishment in one or more domains is so exceptional or developmentally advanced that they require special provisions to meet their education programming needs		X
Individualized Education Program (IEP)	Ever had an IEP in middle school. An IEP is a legal, individualized plan that outlines the special education services and supports that a particular student with disability needs to succeed in school		X
Multilingual learner supports	Ever identified as in-service multilingual learner student, redesignated multilingual learner student, or exited multilingual learner status in middle school		X

Factor	Definition	Grade 9 version	Middle school version
9th grade academy	Participated in a summer orientation program to help rising grade 9 students (summer after grade 8) prepare for high school. Not part of summer academic support programs		X
Other summer academic support program	Participated in one or more programs as a rising grade 7, 8, or 9 student that offer enrichment and support opportunities for small numbers of students, typically from student groups of interest; these programs focus on students with an IEP, multilingual learner students, and (starting in 2023) a program focused on Black, Hispanic, Asian American/Pacific Islander, and Native American communities; captured as a single factor because of the small sample size for each summer support program		X
Academic engagement and achievement in middle school^a (binary indicators unless otherwise noted)			
Attendance rate	Proportion of school days that a student was marked present (continuous variable)		X
Math course attendance rate	Proportion of days that a student was marked present in their main math course (continuous variable)		X
Any suspension	Ever received any in-school or out-of-school suspension		X
Failing grade in any math course	Received a failing grade in a math course in any marking period (such as any quarter or trimester) or on any standard (such as equations or expressions)		X
English language arts proficiency benchmark (Colorado Measures of Academic Success, CMAS, exam)	Met or exceeded the English language arts proficiency benchmark on Colorado's state standardized exam, CMAS		X
Math proficiency benchmark (CMAS exam)	Met or exceeded the math proficiency benchmark on Colorado's state standardized exam, CMAS		X
Learning environment of the school the student attended in middle school or grade 9 (binary indicators unless otherwise noted)			
School characteristic			
<i>Demographic makeup</i>			
Above-average Black student enrollment	School with above-average proportion of Black students compared with the district average for a given year; thresholds range from 13.0 percent to 13.8 percent	X	X
Above-average Hispanic student enrollment	School with above-average proportion of Hispanic students compared with the district average for a given year; thresholds range from 51.7 percent to 56.8 percent	X	X
Above-average National School Lunch Program eligibility	School with above-average proportion of students eligible for the National School Lunch Program compared with the district average for a given year; thresholds range from 59.8 percent to 70.3 percent	X	X

Factor	Definition	Grade 9 version	Middle school version
<i>Academic engagement and achievement</i>			
Above-average attendance rate	School with above-average attendance rate compared with the district average for a given year; thresholds range from 81.2 percent to 89.5 percent	X	X
Above-average suspension rate	School with above-average suspension rate compared with the district average for a given year; suspension rates are calculated as the total number of in-school and out-of-school suspensions divided by total enrollment; thresholds range from 7.0 percent to 10.6 percent, except that in 2021, the average suspension rate was 0.2 percent, likely due to the Covid-19 pandemic	X	X
Above-average family engagement	School with above-average rate of families that fill out district-provided surveys compared with the district average in a given year; survey rates are calculated as the total number of completed surveys divided by total enrollment; thresholds range from 7.2 percent to 58.3 percent	X	X
Above-average math proficiency	High school with above-average mean score on the Preliminary SAT 9 math exam; thresholds range from 414 to 432; or a middle school with above-average proficiency rate (percentage of students meeting or exceeding proficiency benchmarks) on the CMAS math exam; thresholds range from 20.8 percent to 30.4 percent	X	X
<i>School type</i>			
District school	Traditional school operated by the district	X	X
Innovation school	Middle or high school with community-created plans to improve students' experiences and outcomes through the use of innovative practices, such as extending the school day, holding extra teacher training days, and incorporating enrichment programs, such as afterschool Spanish programs or gardening classes (Denver Public Schools, 2024); innovation schools are also allowed some autonomy to foster innovation, including greater control over staffing, scheduling, and budgeting and a pause on state accountability identification timelines, when applicable (Colorado Department of Education, 2024); although some Colorado school districts use innovation status as a reform approach for low-performing schools, only about 30 percent of DPS innovation schools were in the lowest school performance framework categories (Priority Improvement or Turnaround) when they became innovation schools (Colorado Department of Education, 2019)	X	X

Factor	Definition	Grade 9 version	Middle school version
Newcomer center	A high school- or middle school-based center designed for students who are new to the United States, have a history of limited or interrupted education, and have minimal literacy skills in both their home language and English; eligible students receive English instruction that focuses on accelerating both English language skills and content proficiency, with low student-adult ratios	X	X

Teacher characteristics in the school the student attended in middle school or grade 9
(binary indicators unless otherwise noted)

Demographics

Above-average Black, all teachers	School with above-average percentage of Black teachers compared with the district average for a given year; thresholds range from 3.9 percent to 5.0 percent	X	X
Above-average Black, math teachers	School with above-average percentage of Black math teachers compared with the district average for a given year; thresholds range from 3.1 percent to 4.7 percent	X	X
Above-average Hispanic, all teachers	School with above-average percentage of Hispanic teachers compared with the district average for a given year; thresholds range from 10.2 percent to 15.4 percent	X	X
Above-average Hispanic, math teachers	School with above-average percentage of Hispanic math teachers compared with the district average for a given year; thresholds range from 9.9 percent to 15.6 percent	X	X
Above-average White, all teachers	School with above-average percentage of White teachers compared with the district average for a given year; thresholds range from 68.9 percent to 75.7 percent	X	X
Above-average White, math teachers	School with above-average percentage of White math teachers compared with the district average for a given year; thresholds range from 71.9 percent to 78.2 percent	X	X
Above-average male, all teachers	School with above-average percentage of male teachers compared with the district average for a given year; thresholds range from 32.9 percent to 34.7 percent	X	X
Above-average male, math teachers	School with above-average percentage of male math teachers compared with the district average for a given year; thresholds range from 35.0 percent to 44.7 percent	X	X
Above-average ages 20-29, all teachers	School with above-average percentage of teachers ages 20-29 compared with the district average for a given year; thresholds range from 15.9 percent to 25.0 percent	X	X
Above-average ages 20-29, math teachers	School with above-average percentage of math teachers ages 20-29 compared with the district average for a given year; thresholds range from 21.6 percent to 27.8 percent	X	X

Teaching experience and qualifications of school attended

Above-average advanced degrees, all teachers	School with above-average percentage of teachers with advanced degrees (such as master's or doctorate) compared with the sample mean for a given year; thresholds range from 66.1 percent to 69.0 percent	X	X
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Factor	Definition	Grade 9 version	Middle school version
Above-average advanced degrees, math teachers	School with above-average percentage of math teachers with advanced degrees (master's or doctorate) compared with the district average for a given year; thresholds range from 65.5 percent to 73.1 percent	X	X
Above-average alternative certification, all teachers	School with above-average percentage of teachers with alternative certifications compared with the district average for a given year; thresholds range from 2.0 percent to 6.6 percent; alternative certifications include Colorado Alternative Teacher License, which typically allows individuals to teach while completing an approved, one- to two-year teacher preparation program, or participation in a specific alternative route program such as Teach For America or Denver Teaching Fellows	X	X
Above-average alternative certification, math teachers	School with above-average percentage of math teachers with alternative certifications compared with the district average for a given year; thresholds range from 2.4 percent to 12.5 percent; alternative certifications include Colorado Alternative Teacher License, which typically allows individuals to teach while completing an approved, one- to two-year teacher preparation program, or participation in a specific alternative route program such as Teach For America or Denver Teaching Fellows	X	X
Above-average multilingual learner certification, all teachers	School with above-average percentage of teachers with multilingual learner certifications compared with the district average for a given year; thresholds range from 5.5 percent to 9.9 percent	X	X
Above-average multilingual learner certification, math teachers	School with above-average percentage of math teachers with multilingual learner certifications compared with the district average for a given year; thresholds range from 3.1 percent to 8.8 percent	X	X
Above-average math certification, math teachers	School with above-average percentage of math teachers with math certifications compared with the district average for a given year; thresholds range from 56.1 percent to 65.5 percent	X	X
Above-average years of experience, all teachers	School with teachers with above-average years of experience in DPS schools compared with the district average for a given year; thresholds range from 7.0 years to 8.0 years	X	X
Above-average years of experience, math teachers	School with math teachers with above-average years of experience in DPS schools compared with the district average for a given year; thresholds range from 6.7 years to 7.4 years	X	X

Factor	Definition	Grade 9 version	Middle school version
Above-average teacher leaders, all teachers	School with above-average percentage of teacher leaders compared with the district average for a given year (DPS had no teacher leaders in 2015); thresholds range from 5.5 percent to 28.6 percent; teacher leaders are classroom teachers who spend a portion of their time in an additional position (such as Instructional Team Lead or New Teacher Ambassador) that supports the school leadership team	X	X
Above-average teacher leaders, math teachers	School with above-average percentage of math teacher leaders compared with the district average for a given year (DPS had no teacher leaders in 2015); thresholds range from 5.8 percent to 27.9 percent; teacher leaders are classroom teachers who spend a portion of their time in an additional position (such as Instructional Team Lead or New Teacher Ambassador) that supports the school leadership team	X	X
Above-average professional learning attendance, math teachers	School with above-average percentage of math teacher attendance in professional learning compared with the district average for a given year; thresholds range from 0 to 32.6 percent; professional learning is an optional professional development program held during the summer	X	X
Above-average retention, all teachers	School with above-average rates of teacher retention compared with the district average for a given year; thresholds range from 73.6 percent to 83.3 percent	X	X
Above-average retention, math teachers	School with above-average rates of math teacher retention compared with the district average for a given year; thresholds range from 73.6 percent to 86.7 percent	X	X
Student-teacher ratio, all teachers	Ratio of all students to teachers at a school (continuous variable)	X	X
Student-teacher ratio, math teachers	Ratio of all students to math teachers at a school (continuous variable)	X	X
Student-level controls in regression models (all binary indicators)			
Grade 9 cohort	School year during which a student is enrolled in grade 9 for the first time	X	
Integrated math course	Student's main math course integrates multiple strands of math—such as algebra and geometry—into the course	X	
Algebra course	Student's main math course teaches algebraic structures and the manipulation of statements within those structures	X	
Geometry course	Student's main math course teaches properties and relations of points, lines, surfaces, solids, and higher dimensional analogs	X	
Other math course	Student's main math course is a nontypical grade 9 math course—such as calculus, Algebra II, or remedial math support courses	X	

Factor	Definition	Grade 9 version	Middle school version
Multiple math courses	Student took more than one math course during grade 9	X	
School transfer	Changed schools within the school year	X	X

Note: If a factor has a middle school version and a grade 9 version, there are two variables capturing the construct during different grade levels (middle school or grade 9).

a. All middle school binary indicators capture whether the student ever had that experience in middle school (for example, was ever suspended in middle school). These variables are constructed based only on data available in middle school, so some students may have more (or fewer) chances to have some experiences, depending on the number of years they attended DPS schools.

Source: Authors' compilation.

Sample

This study aimed to understand characteristics and experiences of students that were strongly associated with success in grade 9 math for students who attended traditional DPS schools during the regular school year and were in DPS schools at some point in middle school. Specifically, the focal population for this study included:

- Students in traditional DPS schools, which excludes students who were home schooled, in private schools, or in charter schools.
- Students who attended DPS during the regular school year, which excludes students who attended DPS only for summer school.
- Students who attended DPS for at least one middle school grade (grade 6, 7, or 8).
- Students who entered grade 9 in DPS in school year 2017/18, 2018/19, 2020/21, 2021/22, or 2022/23, which excludes students who entered grade 9 in school year 2019/20, during the first year of the Covid-19 pandemic (many schools closed in spring 2020).

Primary analytic sample

17,249 students overall

48 traditional DPS high schools

This focal population included 18,238 students across 48 DPS schools. Not all of these students had the key data needed to address the study's research questions: 95 percent of students had the information needed to determine the primary outcome (passing grade 9 math course), and 78 percent had information on the secondary outcome (meeting the PSAT 9 math proficiency benchmark). (For more on information on how the study handled missing data and on the generalizability of the findings to the focal population, see appendix C.)

The resulting analytic sample for the primary outcome analysis (passing grade 9 math course) consisted of 17,249 students across 48 schools. This included the following samples of students in the student groups of interest in DPS: 2,277 Black students, 8,750 Hispanic students, 2,217 students with an Individualized Education Program (IEP), and 6,583 multilingual learner students.³ The analytic sample for the secondary outcome analysis (meeting the PSAT 9 math proficiency benchmark) included 14,260 students across 48 schools.

Tables A3-A5 summarize the characteristics of the analytic sample. Table A6 provides additional summary statistics on suspension rates by student groups to further contextualize the findings on this factor discussed in the main report.

³ Student groups of interest are not mutually exclusive. For example, a Black student with an IEP will be included in the analyses for Black students and that for students with an IEP. The analytic sample includes 465 Black students with an IEP, 386 Black multilingual learner students, 1,238 Hispanic students with an IEP, 5,550 Hispanic multilingual learner students, and 771 multilingual learner students with an IEP. Data on race/ethnicity provided by DPS are mutually exclusive so the study cannot capture students who are both Black and Hispanic.

Table A3. Sample descriptives and raw data on characteristics and experiences for students who were and those who were not successful in grade 9 math in Denver Public Schools, 2014/15-2022/23

Variable	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
Student characteristics (all binary indicators)					
Male ^a	50.8	49.8	56.8	-7.0*	0
Female ^a	48.7	49.7	42.9	6.8*	0
Black	13.2	12.2	19.8	-7.6*	0
Hispanic	50.9	48.4	65.5	-17.2*	0
White	27.7	30.9	8.4	22.5*	0
Other race/ethnicity ^b	8.2	8.5	6.2	2.3*	0
National School Lunch Program eligibility	61.1	57.2	86.2	-29.0*	2
Home language: English	90.3	90.5	89.2	1.3*	0
Home language: Spanish	7.1	6.8	8.3	-1.5*	0
Home language: Other ^c	2.6	2.6	2.5	0.1	0
Newcomer ^c	0.5	0.5	0.6	-0.1	0
Student experiences					
<i>Received supports in middle school</i> (all binary indicators)					
504 plan ^c	1.4	1.2	2.1	-0.8*	0
Gifted program	17.4	19.6	4.2	15.4*	0
Individualized Education Program	12.8	11.7	19.8	-8.2*	0
Multilingual learner supports ^d	37.7	36.7	43.5	-6.9*	0
9th grade academy	56.1	60.2	32.7	27.5*	0
Other summer academic support program ^c	3.4	3.5	2.3	1.1*	0
<i>Academic achievement and engagement in middle school</i> (binary indicators unless otherwise noted)					
Attendance rate (continuous variable)	90.5	91.8	82.2	9.5*	15
Math course attendance rate (continuous variable)	76.8	78.8	64.7	14.1*	2
Any suspension	16.6	13.3	36.9	-23.6*	0
Failing grade in any math course	56.0	52.4	78.2	-25.8*	4
English language arts proficiency benchmark (Colorado Measures of Academic Success, CMAS, exam)	47.5	53.2	11.4	41.8*	12
Math proficiency benchmark (CMAS exam)	34.7	39.6	3.7	35.9*	12

Variable	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
Regression controls (all binary indicators)					
<i>Grade 9 cohort</i>					
2017/18	19.5	18.7	25.7	-7.0*	0
2018/19	20.0	19.2	25.5	-6.3*	0
2020/21	19.0	21.3	0.7	20.7*	0
2021/22	20.5	20.2	23.0	-2.8*	0
2022/23	21.0	20.5	25.1	-4.5*	0
Integrated math course	82.2	81.2	89.1	-7.9*	1
Algebra course	7.8	7.7	8.6	-0.8	1
Geometry course	5.8	6.5	0.9	5.6*	1
Other math course ^c	4.2	4.6	1.4	3.2*	1
Multiple math courses	25.3	23.6	37.1	-13.5*	0
School transfer	10.3	8.2	23.0	-14.8*	0

* Significant at $p < .05$.

Note: Mutually exclusive categories (race/ethnicity and home language) may not sum to 100 because of rounding.

a. Percentages do not sum to 100 because some students did not identify as either male or female.

b. Includes students who identify as American Indian or Alaska Native, Asian, multiple races, or Native Hawaiian or Other Pacific Islander.

c. Factors that were less than 5 percent of the study sample are not discussed in the main report.

d. Includes all students who received any multilingual learner supports during the study period.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Table A4. Characteristics of the schools attended by students who were and by those who were not successful in grade 9 math in Denver Public Schools, 2014/15-2022/23

Factor	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
High school characteristics					
<i>School demographics, academic achievement and engagement, and type</i> (all binary indicators)					
Above-average Black student enrollment	46.2	46.4	45.5	0.9	0
Above-average Hispanic student enrollment	46.4	44.5	57.4	-12.9*	0
Above-average National School Lunch Program eligibility	48.0	45.3	63.7	-18.4*	0
Newcomer center	16.5	16.1	18.6	-2.5*	0
Above-average attendance rate	63.0	65.7	46.8	18.9*	7
Above-average suspension rate	89.5	88.6	95.4	-6.8*	12
Above-average math proficiency	51.9	54.6	36.5	18.1*	0
District school	93.2	92.4	98.2	-5.8*	1

Factor	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
Innovation school	6.8	7.6	1.8	5.8*	1
Above-average family engagement	44.3	45.5	36.0	9.5*	4
Teacher characteristics (binary indicators unless otherwise indicated)					
Above-average advanced degrees, all teachers	59.2	61.0	47.8	13.2*	1
Above-average advanced degrees, math teachers	64.9	65.8	59.6	6.2*	10
Above-average ages 20-29, all teachers	39.7	38.5	46.2	-7.7*	1
Above-average ages 20-29, math teachers	44.9	45.1	44.3	0.7	10
Above-average Black, all teachers	31.0	30.9	30.6	0.2	1
Above-average Black, math teachers	31.0	30.5	33.6	-3.1*	10
Above-average alternative certification, all teachers	38.0	35.8	51.9	-16.1*	1
Above-average alternative certification, math teachers	23.1	23.0	24.7	-1.7	10
Above-average multilingual learner certification, all teachers	28.6	27.5	35.3	-7.8*	1
Above-average multilingual learner certification, math teachers	40.8	41.3	37.0	4.4*	10
Above-average math certification, math teachers	45.5	46.7	38.1	8.6*	10
Above-average years of experience, all teachers	55.1	56.2	49.8	6.4*	1
Above-average years of experience, math teachers	51.6	52.3	46.6	5.7*	10
Above-average male, all teachers	80.8	81.2	78.2	3.0*	1
Above-average male, math teachers	44.1	44.6	41.8	2.8*	10
Above-average Hispanic, all teachers	41.8	40.5	48.5	-7.9*	1
Above-average Hispanic, math teachers	34.6	34.1	38.1	-4.0*	10
Above-average teacher leaders, all teachers	46.0	44.6	54.8	-10.2*	8
Above-average teacher leaders, math teachers	42.8	42.8	42.5	0.3	10
Above-average professional learning attendance, math teachers	18.0	17.5	21.9	-4.4*	10
Above-average retention, all teachers	71.9	72.8	65.9	6.9*	1
Above-average retention, math teachers	67.0	67.8	62.2	5.6*	10
Above-average White, all teachers	59.3	60.3	53.9	6.3*	1
Above-average White, math teachers	59.7	60.3	56.0	4.2*	10
Student-teacher ratio, all teachers (continuous variable)	5.5	5.6	5.3	0.3*	1
Student-teacher ratio, math teachers (continuous variable)	26.5	26.8	24.6	2.2*	9

Factor	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
Middle school characteristics					
<i>School demographics, academic achievement and engagement, and type</i> (all binary indicators)					
Newcomer center	10.7	10.4	11.8	-1.4*	1
Above-average attendance rate	98.7	99.0	96.9	2.1*	16
Above-average suspension rate	82.4	81.7	86.3	-4.5*	2
Above-average Hispanic student enrollment	51.4	49.2	64.0	-14.8*	1
Above-average National School Lunch Program eligibility	55.8	52.7	73.5	-20.9*	1
Above-average Black student enrollment	50.9	50.8	51.3	-0.5	1
District school	93.2	93.2	93.3	-0.1	1
Innovation school	14.5	15.4	9.0	6.4*	1
Above-average math proficiency	51.3	54.5	33.1	21.3*	3
Above-average family engagement	65.6	66.5	60.7	5.8*	5
<i>Teacher characteristics</i> (binary indicators unless otherwise noted)					
Above-average advanced degrees, all teachers	65.2	65.2	65.5	-0.4	4
Above-average advanced degrees, math teachers	64.2	65.7	53.8	11.9*	17
Above-average ages 20-29, all teachers	74.0	73.6	75.7	-2.1*	4
Above-average ages 20-29, math teachers	79.7	79.5	80.9	-1.4	17
Above-average Black, all teachers	45.7	44.2	54.5	-10.3*	4
Above-average Black, math teachers	44.3	43.6	49.9	-6.3*	17
Above-average alternative certification, all teachers	65.8	64.8	71.2	-6.4*	4
Above-average alternative certification, math teachers	58.1	57.9	59.4	-1.5	17
Above-average multilingual learner certification, all teachers	64.2	65.0	58.6	6.5*	4
Above-average multilingual learner certification, math teachers	46.0	45.8	46.3	-0.5	17
Above-average math certification, math teachers	66.5	66.4	66.1	0.3	4
Above-average years of experience, all teachers	43.3	43.1	44.7	-1.5	4
Above-average years of experience, math teachers	38.5	38.2	40.3	-2.1	17
Above-average male, all teachers	46.8	46.0	50.8	-4.8*	4
Above-average male, math teachers	54.3	54.0	57.4	-3.4*	17
Above-average Hispanic, all teachers	43.0	40.8	56.7	-15.9*	4
Above-average Hispanic, math teachers	48.3	46.9	58.0	-11.1*	17

Factor	Grade 9 students overall (percent) (n = 17,249)	Successful (percent) (n = 13,855)	Not successful (percent) (n = 3,394)	Difference (percentage points)	Missing (percent)
Above-average number teacher leaders, all teachers	58.8	57.9	64.6	-6.8*	13
Above-average professional learning attendance, math teachers	28.4	29.0	23.9	5.1*	17
Above-average retention, all teachers	62.9	65.1	48.3	16.8*	4
Above-average retention, math teachers	68.3	69.8	57.4	12.4*	17
Above-average White, all teachers	68.2	70.4	55.6	14.9*	4
Above-average White, math teachers	68.0	69.3	59.2	10.1*	17
Student-teacher ratio, all teachers (continuous variable)	15.6	15.6	15.7	-0.1	4
Student-teacher ratio, math teachers (continuous variable)	70.7	71.2	67.9	3.2*	17

* Significant at $p < .05$.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Table A5. Sample descriptive statistics for students in multiple student groups of interest in Denver Public Schools, 2014/15-2022/23

Variable	Students with an Individualized Education Program (IEP) (percent) (n = 2,217)	Multilingual learner students (percent) (n = 6,583)
Black students	21	6
Hispanic students	56	84
Students with an IEP	100	12

Note: This table shows the percentage of students with an IEP who are also Black or Hispanic and the percentage of multilingual learner students who are also Black, Hispanic, or have an IEP.

Source: Author's analysis based on 2013/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Table A6. Middle school suspension rates by student group of interest in Denver Public Schools, 2014/15-2022/23

Variable	Percent of students suspended (n = 17,249)
Grade 9 students overall	17
Black students	32
Hispanic students	18
Students with an Individualized Education Program	27
Multilingual learner students	16

Note: This table shows the percentage of each student group that experienced an in-school or out-of-school suspension during any middle school year.

Source: Author's analysis based on 2013/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Analytic methods

This section describes the analytic methods used to answer the study’s two research questions.

1. What student characteristics and experiences are strongly associated with grade 9 math success in DPS?
2. How do the strongest associations with success in grade 9 math differ for student groups of interest in DPS?

Research question 1. The study used regression analyses that account for contextual factors that may shape grade 9 math success and that show the relative contribution of each factor to success. Regression analyses identified the student characteristics and experiences that were most strongly associated with grade 9 math success for DPS students. Specifically, the study estimated the following equation using a linear probability model⁴ and Huber-White sandwich standard errors to account for clustering at the school level:

$$(A1) \quad \text{Math Success}_{ist} = \text{Student}'_{ist}\beta + \text{HS}'_{st}\gamma + \text{MS}'_{st}\delta + \tau_t + \epsilon_{ist}.$$

Math Success is grade 9 math success, which is the outcome variable for student i , in school s , in grade 9 cohort t . The primary measure of grade 9 math success used in the study was passing a student’s main grade 9 math course. A secondary measure was meeting proficiency standards on the PSAT 9 math exam. *Student* is a vector of student-level characteristics and experiences. *HS* is a vector of characteristics for the high school a student attended in grade 9, including teacher characteristics. *MS* is a vector of characteristics for the middle school (grades 6–8) that a student attended, including teacher characteristics. *HS* and *MS* are defined as the schools in which a student was enrolled for the longest duration in grade 9 and grades 6–8, respectively. τ_t are cohort fixed effects, which control for any unobserved factors common to a cohort, such as attending school during the height of the Covid-19 pandemic. All regressions include student-level controls, including the type of math course a student took in grade 9 and whether a student changed schools during the school year. (For a description of all factors and controls included in the analysis, see table A2.)

The coefficients of interest (β , γ , and δ) are presented as marginal effects—for example, the difference in the probability that a student who is eligible for the National School Lunch Program (NSLP) program was successful in grade 9 math compared with a student who is not eligible, or the difference in the probability of being successful in grade 9 math if a student attends a school with a newcomer center compared with a school without a newcomer center.

Research question 2. To answer research question 2 on factors with the strongest association with grade 9 math success, the study team conducted subgroup analyses for each of the four student groups of interest in DPS: Black students, Hispanic students, students with an IEP, and multilingual learner students. Equation A1 was estimated separately for each subgroup. All coefficients are presented as marginal effects.

The study considered the statistical and practical significance of a factor to define a strong association. An association was considered to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience (a one-unit change in a binary factor or a one-standard-deviation change in a continuous variable) was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success—equivalent to increasing the likelihood from, for example, 85 percent to 90 percent. While not statistically derived, a 5 percentage point difference is of practical significance for DPS.

⁴ When a model’s outcome is binary, linear probability models can be as effective as logistic regression models in estimating probabilities and produce more easily interpretable results (Gomila, 2021). The study conducted a sensitivity analysis using a logit model, which produced consistent findings.

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Appendix B. Supporting analyses

This appendix provides supporting analyses for the findings in the main report. Specifically, it provides regression results from estimating equation A1 in appendix A to identify the characteristics and experiences associated with grade 9 math success. Table B1 presents the regression results for the pooled sample of grade 9 students overall and for each student group of interest (Black students, Hispanic students, students with an Individualized Education Program, and multilingual learner students). The regression results in table B1 correspond to the findings discussed in the main report. Only regression coefficients for a factor that is strongly associated with math success for at least one of the five student groups are presented in table B1. Factors that are strongly associated with grade 9 math success are indicated with a dagger. For the full list of factors included in all regression models, see table A2 in appendix A.

An association is considered to be a **strong association** if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience (a one-unit change in a binary factor or a one-standard-deviation change in a continuous variable) was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success.

Table B1. Factors strongly associated with grade 9 math success in Denver Public Schools, 2014/15–2022/23 (difference in likelihood of math success)

Factor	Grade 9 students overall (n = 17,249)	Blacks students (n = 2,277)	Hispanic students (n = 8,750)	Students with an Individualized Education Program (n = 2,206)	Multilingual learner students (n = 6,523)
Student characteristic (binary indicator)					
National School Lunch Program eligibility	-0.016* (0.008) [0.05]	-0.031 (0.018) [0.10]	-0.014 (0.012) [0.24]	-0.057*† (0.025) [0.03]	0.006 (0.012) [0.61]
Middle school experiences (all binary indicators unless otherwise indicated)					
504 plan	-0.028 (0.020) [0.17]	0.064 (0.084) [0.46]	-0.093*† (0.040) [0.03]	0.013 (0.047) [0.78]	-0.033 (0.043) [0.44]
9th grade academy	0.046* (0.013) [0.00]	0.060*† (0.022) [0.01]	0.057*† (0.015) [0.00]	0.041 (0.027) [0.14]	0.041* (0.014) [0.00]
Attendance rate (continuous variable)	0.061*† (0.005) [0.00]	0.047* (0.012) [0.00]	0.075*† (0.009) [0.00]	0.063*† (.011) [0.00]	0.083*† (.008) [0.00]
Any suspension	-0.106*† (0.007) [0.00]	-0.094*† (0.012) [0.00]	-0.112*† (0.010) [0.00]	-0.118*† (0.017) [0.00]	-0.114*† (0.015) [0.00]

Factor	Grade 9 students overall (n = 17,249)	Blacks students (n = 2,277)	Hispanic students (n = 8,750)	Students with an Individualized Education Program (n = 2,206)	Multilingual learner students (n = 6,523)
Any failing grade in a math course	-0.068*† (0.016) [0.00]	-0.097*† (0.025) [0.00]	-0.105*† (0.015) [0.00]	-0.084*† (0.027) [0.00]	-0.112*† (0.017) [0.00]
English language arts proficiency benchmark (Colorado Measures of Academic Success exam)	0.066*† (0.007) [0.00]	0.075*† (0.021) [0.00]	0.062*† (0.010) [0.00]	0.088*† (0.033) [0.01]	0.069*† (0.009) [0.00]
High school characteristics (all binary indicators)					
Above-average Hispanic student enrollment	0.067*† (0.023) [0.00]	0.017 (0.040) [0.68]	0.100*† (0.036) [0.01]	0.072 (0.055) [0.20]	0.057 (0.036) [0.13]
Above-average National School Lunch Program eligibility	-0.094*† (0.044) [0.04]	-0.070 (0.135) [0.61]	-0.139*† (0.054) [0.01]	-0.025 (0.091) [0.78]	-0.113 (0.065) [0.09]
Newcomer center	-0.053*† (0.018) [0.01]	-0.068 (0.042) [0.11]	-0.073*† (0.022) [0.00]	-0.105*† (0.042) [0.02]	-0.074*† (0.025) [0.01]
Above-average suspension rate	-0.046* (0.019) [0.02]	-0.026 (0.043) [0.56]	-0.068*† (0.025) [0.01]	-0.048 (0.047) [0.31]	-0.059*† (0.026) [0.03]
Above-average family engagement	-0.032 (0.019) [0.10]	-0.077*† (0.033) [0.02]	-0.026 (0.023) [0.26]	-0.038 (0.039) [0.33]	-0.013 (0.026) [0.61]
Innovation school	0.009 (0.032) [0.78]	-0.085 (0.068) [0.22]	0.060 (0.039) [0.13]	0.076 (0.074) [0.31]	0.083*† (0.041) [0.05]
Above-average grade 9 math teachers with advanced degrees	-0.019 (0.015) [0.23]	-0.059*† (0.027) [0.04]	-0.017 (0.024) [0.48]	-0.019 (0.030) [0.52]	-0.011 (0.025) [0.66]
Above-average teacher leaders, all teachers	-0.028 (0.015) [0.06]	-0.105*† (0.031) [0.00]	-0.014 (0.021) [0.52]	-0.030 (0.034) [0.38]	-0.007 (0.025) [0.79]
Above-average teacher leaders, math teachers	0.043* (0.010) [0.00]	0.074*† (0.019) [0.00]	0.059*† (0.014) [0.00]	0.055 (0.028) [0.06]	0.048* (0.016) [0.00]
Middle school characteristics (all binary indicators)					
Above-average National School Lunch Program eligibility	0.010 (0.014) [0.45]	0.015 (0.032) [0.64]	0.015 (0.018) [0.40]	0.131*† (0.036) [0.00]	0.011 (0.020) [0.58]
Above-average family engagement	0.013 (0.009) [0.13]	0.034 (0.018) [0.06]	0.005 (0.010) [0.62]	0.059*† (0.018) [0.00]	0.006 (0.014) [0.67]

Factor	Grade 9 students overall (n = 17,249)	Blacks students (n = 2,277)	Hispanic students (n = 8,750)	Students with an Individualized Education Program (n = 2,206)	Multilingual learner students (n = 6,523)
Above-average math proficiency benchmark	0.025 (0.013) [0.05]	0.078*† (0.034) [0.03]	0.038 (0.020) [0.06]	0.099*† (0.030) [0.00]	0.035 (0.020) [0.09]
Innovation school	0.001 (0.015) [0.94]	0.037 (0.034) [0.27]	0.031 (0.025) [0.22]	-0.105*† (0.047) [0.03]	0.024 (0.031) [0.44]
Above-average Black, math teachers	-0.040* (0.010) [0.00]	-0.055*† (0.019) [0.00]	-0.019 (0.016) [0.24]	-0.042 (0.032) [0.20]	-0.030 (0.019) [0.11]
Above-average male, math teachers	-0.004 (0.006) [0.51]	-0.075*† (0.028) [0.01]	0.003 (0.009) [0.74]	0.001 (0.019) [0.97]	0.003 (0.010) [0.75]
Above-average advanced degrees, all teachers	-0.028* (0.011) [0.01]	-0.073*† (0.022) [0.00]	-0.029 (0.015) [0.06]	-0.038 (0.025) [0.13]	-0.023 (0.017) [0.20]
Adjusted R-squared	0.23	0.22	0.22	0.20	0.21

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with grade 9 math success.

Note: The table shows the coefficients from ordinary least squares regressions that estimated the association between student characteristics and experiences and grade 9 math success (defined as passing the main grade 9 course). For grade 9 students overall, each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. For student groups of interest, each coefficient represents the adjusted difference in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students in the same student group of interest who did not. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. The middle school attendance rate was a continuous factor with a standard deviation of 0.094. All models control for the factors listed in table A2 in appendix A.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Appendix C. Other analyses

This appendix provides additional detail on the following:

- Findings on the study’s secondary outcome: proficiency on the Preliminary SAT 9 (PSAT 9) math exam.
- Details on how the study team addressed missing data.
- Findings on the association between characteristics of students’ middle school or high school and grade 9 math success.
- Findings on the association between attending the 9th grade academy summer program and grade 9 math success for student groups of interest.
- Exploratory analyses examining the association between grade 9 student experiences and grade 9 math success.
- Findings that include students in charter schools in the study sample.

Factors strongly associated with proficiency on the Preliminary SAT 9 math exam differed from those that were strongly associated with grade 9 math success

As a secondary measure of math success, the study team identified the student characteristics and experiences that were associated with proficiency on the PSAT 9 math exam, which Denver Public Schools (DPS) began administering to all grade 9 students in 2018 to comply with state legislation. In 2023, less than half of all grade 9 DPS test takers met or exceeded grade-level benchmarks on the PSAT 9 math exam (Colorado Department of Education, 2024). Moreover, only about a quarter of Black or Hispanic students, about 1 in 10 students with an Individualized Education Program (IEP), and fewer than 1 in 10 multilingual learner students met or exceeded benchmarks for grade-level performance on the PSAT 9. This section discusses the student characteristics and experiences that were strongly associated with proficiency on the PSAT 9 math exam and how they differed from those associated with grade 9 math success.

Though both exam scores and course grades are important measures of math success, different factors were associated with success on each outcome, for the most part. There were three notable differences between factors associated with proficiency on the PSAT 9 math and grade 9 math success. First, for each outcome, the factor that was the most strongly associated—positively or negatively—was not strongly associated with the other outcome. Specifically, receiving any suspension in middle school was most strongly associated with being unsuccessful in a grade 9 math course, while proficiency on the Colorado Measures of Academic Success (CMAS) math exam in middle school was most strongly associated with proficiency on the PSAT 9 math exam (figure C1). The finding for suspensions could imply that the mechanisms through which suspension is associated with math course success, such as time in the class, are not as closely linked to standardized test score outcomes. The finding for CMAS math exam proficiency suggests that the type of content mastery that the CMAS and PSAT measure could be well aligned.

Second, middle school academic supports, including being a student with an IEP or in the gifted program, were strongly associated with PSAT 9 math proficiency but not with grade 9 math success. Specifically, students with an IEP were 5.9 percentage points less likely to be proficient on the PSAT 9 math exam than students without an IEP. Conversely, students in the gifted program during middle school were 12.5 percentage points more likely to be proficient on the PSAT 9 math exam than were students who were not in the program. This could be because

the assessments used to identify students to receive either gifted program supports or an IEP measure similar skills as standardized exams like the PSAT 9.

Third, student characteristics were strongly negatively associated with proficiency on the PSAT 9 math exam but were not strongly associated with grade 9 math success. Specifically, Black or Hispanic students were less likely to be proficient on the PSAT 9 math exam than were similar White students (see figure C1). These findings hold even after adjusting for the likelihood of a student taking the PSAT and so are not driven by differences in the characteristics of students who take the PSAT 9 exam compared with the full study sample (table C2).

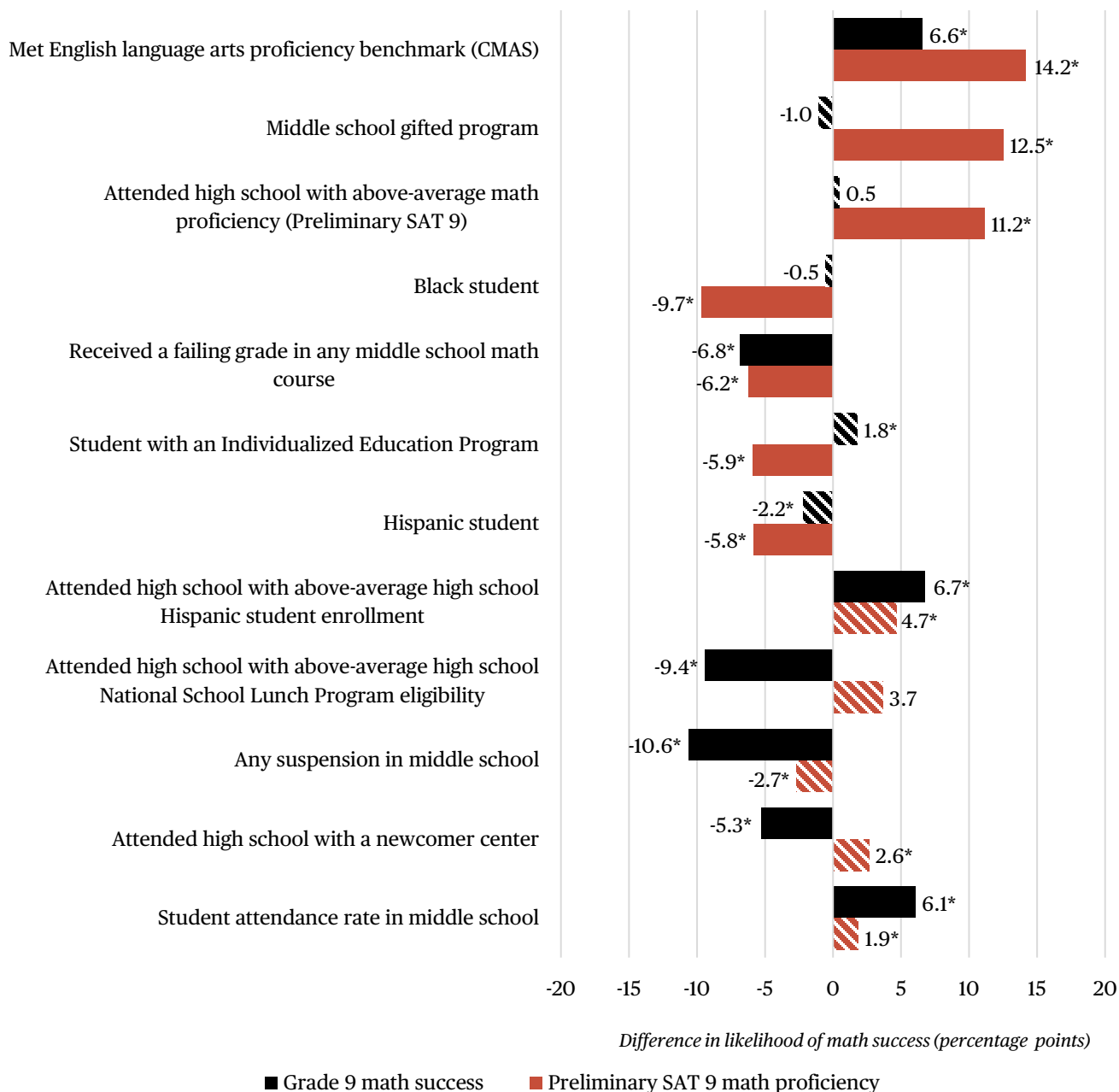
Only two student experiences were strongly associated with both proficiency on the PSAT 9 math exam and grade 9 math success: meeting the proficiency benchmark on the CMAS English language arts (ELA) exam (positive association) and receiving a failing grade in any middle school math course (negative association; see figure C1).

Regression results from estimating equation A1 in appendix A for the pooled sample (all grade 9 students) and separately by student groups of interest (Black students, Hispanic students, students with an IEP, and multilingual learner students) to identify the characteristics and experiences associated with meeting the proficiency benchmark on the PSAT math exam are presented in table C1. Only regression coefficients for a factor that is strongly associated with math success for at least one of the five student groups are presented. For the full list of factors included in all regression models, see table A2 in appendix A.

DPS may want to consider whether there are differences in the types of skills and knowledge measured by course grades and standardized tests and distinguish between interventions that support each outcome. Course evaluation and standardized tests may capture different types of knowledge and require different types of student skills, or courses may define success in different ways (Suurtamm et al., 2016). These findings suggest that a single intervention cannot be assumed to simultaneously influence course grades and standardized test scores, even in the same subject area. In planning efforts to understand and improve grade 9 math success, DPS could continue to identify the primary outcome it aims to influence while also exploring whether other outcomes change in tandem.

Notably, student characteristics, including race/ethnicity, newcomer status, and eligibility for the National School Lunch Program (NSLP), were strongly associated with meeting the PSAT 9 math proficiency benchmark, while no student characteristics had strong associations with grade 9 math success. However, one key limitation of this analysis is that the findings may not generalize to the focal population and may be driven by differences in which students are likely to take the PSAT exam. A more detailed discussion of this limitation is included in the missing data section of this appendix. To improve success on the PSAT 9 math exam, DPS might consider incorporating student characteristics (including NSLP eligibility and whether a student has an IEP; see Capraro et al., 2000) and scores from middle school math standardized exams (Watts et al., 2014) into an early warning indicator system that identifies students for additional support, such as tutoring or preparation courses for standardized exams.

Figure C1. Factors strongly associated with meeting the proficiency benchmark on the Preliminary SAT 9 math standardized exam differed from those strongly associated with math course success, 2014/15-2022/23



* Significant at $p < .05$.

CMAS is Colorado Measures of Academic Success (standardized exams).

Note: The factor most strongly associated with proficiency on the PSAT 9 math exam, meeting proficiency on the Colorado Measures of Academic Success middle school math standardized exam (46.9 percentage points), is not displayed to avoid skewing the horizontal axis. This figure shows the regression coefficients for the 12 factors strongly associated with meeting or exceeding proficiency on the PSAT 9 math exam for Denver Public School students overall (binary variables) alongside the coefficients for passing the grade 9 math course (grade 9 math success). The solid bars indicate strong associations, while the striped bars indicate no strong associations. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. Each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. For student characteristics, the study compares Black or Hispanic students with similar White students. Regression results are in table C1 and table B1 in appendix B, and the list of all variables included in the regression are in table A2 in appendix A.

Source: Authors' analysis based on 2024/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Table C1. Factors most strongly associated with meeting the Preliminary SAT (PSAT) 9 proficiency benchmark in Denver Public Schools, 2014/15–2022/23 (difference in likelihood of PSAT 9 math proficiency)

Factor	Grade 9 students overall (n = 14,260)	Black students (n = 1,647)	Hispanic student (n = 7,058)	Students with an Individualized Education Program (n = 1,440)	Multilingual learner students (n = 5,406)
Student background					
Black	-0.097*† (0.014) [0.00]	na	na	-0.055*† (0.012) [0.00]	-0.006 (0.028) [0.83]
Hispanic	-0.058*† (0.010) [0.00]	na	na	-0.037 (0.019) [0.06]	-0.012 (0.027) [0.67]
Other race/ethnicity	-0.024 (0.013) [0.06]	na	na	-0.026 (0.037) [0.48]	0.063*† (0.027) [0.03]
Home language: other	0.020 (0.027) [0.45]	0.008 (0.038) [0.83]	0.200*† (0.054) [0.00]	-0.026 (0.030) [0.39]	0.020 (0.027) [0.47]
Middle school experiences					
504 plan	-0.035 (0.025) [0.16]	-0.024 (0.033) [0.49]	-0.058*† (0.023) [0.02]	0.049 (0.059) [0.41]	-0.109*† (0.026) [0.00]
Gifted program	0.125*† (0.011) [0.00]	0.124*† (0.046) [0.01]	0.155*† (0.016) [0.00]	0.369*† (0.091) [0.00]	0.174*† (0.020) [0.00]
Individualized Education Program	-0.059*† (0.009) [0.00]	-0.039* (0.014) [0.01]	-0.047* (0.008) [0.00]	0.046 (0.040) [0.25]	-0.042* (0.010) [0.00]
Multilingual learner supports	-0.011 (0.007) [0.11]	0.055*† (0.020) [0.01]	-0.023* (0.009) [0.01]	-0.021 (0.018) [0.24]	0.119 (0.076) [0.12]
Any failing grade in a math course	-0.062*† (0.011) [0.00]	-0.057*† (0.013) [0.00]	-0.061*† (0.010) [0.00]	-0.013 (0.017) [0.45]	-0.071*† (0.011) [0.00]
English language arts proficiency (Colorado Measures of Academic Success, CMAS, exam)	0.142*† (0.014) [0.00]	0.091*† (0.037) [0.02]	0.137*† (0.019) [0.00]	0.120*† (0.032) [0.00]	0.147*† (0.020) [0.00]
Math proficiency (CMAS exam)	0.469*† (0.015) [0.00]	0.558*† (0.024) [0.00]	0.484*† (0.017) [0.00]	0.400*† (0.075) [0.00]	0.484*† (0.019) [0.00]
High school characteristics					
Above-average Black student enrollment	0.025 (0.014) [0.08]	0.062*† (0.026) [0.02]	0.018 (0.016) [0.27]	0.003 (0.028) [0.91]	0.028 (0.020) [0.18]

Factor	Grade 9 students overall (n = 14,260)	Black students (n = 1,647)	Hispanic student (n = 7,058)	Students with an Individualized Education Program (n = 1,440)	Multilingual learner students (n = 5,406)
Above-average National School Lunch Program eligibility	0.037 (0.042) [0.39]	-0.167*† (0.068) [0.02]	0.054 (0.049) [0.28]	-0.001 (0.043) [0.98]	0.035 (0.046) [0.46]
Above-average math proficiency (PSAT 9)	0.112*† (0.039) [0.01]	-0.078 (0.064) [0.23]	0.121*† (0.036) [0.00]	0.051 (0.035) [0.16]	0.078 (0.042) [0.07]
Innovation school	-0.035 (0.020) [0.09]	0.032 (0.049) [0.52]	-0.048 (0.028) [0.09]	-0.138*† (0.046) [0.00]	0.029 (0.029) [0.32]
Above-average Hispanic, grade 9 math teachers	0.003 (0.013) [0.83]	-0.078*† (0.027) [0.01]	0.006 (0.013) [0.62]	0.009 (0.021) [0.67]	-0.017 (0.019) [0.37]
Above-average White, all teachers	-0.007 (0.011) [0.54]	-0.065*† (0.027) [0.02]	0.001 (0.011) [0.93]	-0.012 (0.020) [0.54]	0.007 (0.017) [0.67]
Above-average advanced degrees, all teachers	0.012 (0.010) [0.22]	0.051*† (0.014) [0.00]	0.019 (0.012) [0.11]	0.015 (0.016) [0.34]	0.012 (0.012) [0.32]
Above-average advanced degrees, grade 9 math teachers	-0.015 (0.011) [0.20]	-0.057*† (0.027) [0.04]	0.001 (0.017) [0.94]	-0.033* (0.014) [0.02]	-0.017 (0.013) [0.19]
Above-average years of experience, all teachers	-0.042* (0.012) [0.00]	-0.050 (0.035) [0.16]	-0.047* (0.015) [0.00]	-0.060*† (0.024) [0.02]	-0.008 (0.014) [0.59]
Adjusted R-squared	0.583	0.439	0.449	0.382	0.463

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with meeting the Preliminary SAT (PSAT) 9 math proficiency benchmark.

na is not applicable because the factor is involved in defining the student group, would not have any variation, and was thus omitted for the student group of interest model.

Note: This table shows the coefficients from ordinary least squares regressions that estimated the association between student characteristics and experiences and meeting the Preliminary SAT (PSAT) 9 math proficiency benchmark. For grade 9 students overall, each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. For student groups of interest, each coefficient represents the adjusted difference in the likelihood of PSAT 9 math proficiency for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students in the same student group of interest who did not. For student characteristics, the study compared Black or Hispanic students with similar White students. The table presents coefficients only for factors with strong associations with PSAT 9 math proficiency. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience (a one-unit change in a binary factor or a one-standard-deviation change in a continuous variable) was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. All models control for the factors listed in table A2 in appendix A. Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Missing data

Missing data on student characteristics or experiences. No students were excluded from the analysis because they lacked information on student characteristics or experiences. To maximize the number of students included in the analysis, the study team imputed missing values for about 45 percent of students who were missing at least one factor. All regression models included a dummy variable adjustment by setting any missing factor values to constants and including missing value flag variables as additional covariates in regression models.

Missing outcome data. The analysis for this report excluded students with missing outcome data. The study analyzed success in grade 9 math (using the primary outcome) for 95 percent of the focal population. Key characteristics and experiences of students did not differ systematically between the students who did and those who did not have outcome data (table C2). Differences between the two groups were less than 0.05 standard deviation units for all variables.

Table C2. Students in the analytic sample for the primary outcome (grade 9 math success) did not differ systematically from those in the focal population, 2014/15–2022/23

Variable	Students in focal population		Students in analytic sample		Difference in means (standard deviation units)
	Mean (N = 18,238)	Standard deviation of mean	Mean (n = 17,249)	Standard deviation of mean	
Student characteristics					
Male	0.511	0.500	0.508	0.500	-0.01
Female	0.484	0.500	0.488	0.500	0.01
White	0.272	0.445	0.279	0.448	0.02
Black	0.134	0.341	0.132	0.339	-0.01
Hispanic	0.513	0.500	0.507	0.500	-0.01
Other race/ethnicity	0.081	0.273	0.082	0.275	0.00
National School Lunch Program eligibility	0.618	0.486	0.610	0.488	-0.02
Home language: English	0.902	0.297	0.904	0.295	0.01
Home language: Spanish	0.072	0.258	0.070	0.256	-0.01
Home language: other	0.026	0.159	0.026	0.160	0.00
Newcomer	0.005	0.073	0.005	0.071	-0.01
Middle school experiences					
504 plan	0.014	0.118	0.014	0.116	0.00
Gifted program	0.162	0.368	0.169	0.375	0.02
Individualized Education Program	0.143	0.350	0.138	0.345	-0.01
Multilingual learner supports	0.375	0.484	0.376	0.484	0.00
9th grade academy	0.540	0.498	0.564	0.496	0.05 ^a
Any suspension	0.170	0.376	0.165	0.372	-0.01
Any failing grade in a math course	0.566	0.496	0.559	0.497	-0.01
Math course attendance rate	0.762	0.190	0.769	0.187	0.03
English language arts proficiency benchmark (CMAS)	0.465	0.499	0.477	0.499	0.02
Math proficiency benchmark (CMAS)	0.338	0.473	0.349	0.477	0.02
Secondary outcome					
Met Preliminary SAT 9 (PSAT) math proficiency benchmark	0.404	0.491	0.407	0.491	0.01

CMAS is Colorado Measures of Academic Success (standardized exams).

Note: This table presents means of student characteristics, experiences, and outcome across two groups: the focal population of students the study aims to generalize to and the analytic sample of students the study findings are based on. Differences in means larger than 0.05 standard deviations are considered large; none of the differences in means for the key variables in this table met this threshold.

a. The difference between the mean of students attending the 9th grade academy in the study’s focal populations compared with the analytic sample was 0.049 standard deviation units but is presented as .05 due to rounding. The study does not consider this to be a systematic difference between students in the analytic sample and the focal population.

Source: Authors’ analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

The study was able to analyze factors associated with PSAT 9 math proficiency (the secondary outcome) for 78 percent of the focal population of students. These students did systematically differ from those in the focal population (table C3). For example, students included in the study (the secondary outcome analytic sample) were more likely to be White, have higher math class attendance, and pass their grade 9 math course. They were less likely to be Black, be eligible for the NSLP, have an Individualized Education Program (IEP), be suspended in middle school, or receive any failing grade in a middle school math course. Therefore, one key limitation of the secondary outcome analysis is that the findings may not generalize to the focal population and may be driven by differences in the students who are likely to take the PSAT exam.

Table C3. Students in the analytic sample for the secondary outcome analysis (meeting the Preliminary SAT 9 proficiency benchmark) differed systematically from those in the focal population, 2014/15-2022/23

Variable	Students in focal population		Students in analytic sample		Difference in means (standard deviation units)
	Mean (N = 18,238)	Standard deviation of mean	Mean (n = 14,260)	Standard deviation of mean	
Student characteristic					
Male	0.511	0.500	0.505	0.500	-0.01
Female	0.484	0.500	0.490	0.500	0.01
White	0.272	0.445	0.306	0.461	0.08*
Black	0.134	0.341	0.115	0.320	-0.05*
Hispanic	0.513	0.500	0.495	0.500	-0.04
Other race/ethnicity	0.081	0.273	0.084	0.277	0.01
Home language: English	0.902	0.297	0.905	0.293	0.01
Home language: Spanish	0.072	0.258	0.068	0.252	-0.01
Home language: other	0.026	0.159	0.026	0.160	0.00
National School Lunch Program eligibility	0.618	0.486	0.579	0.494	-0.08*
Newcomer	0.005	0.073	0.004	0.064	-0.02
Middle school experience					
504 plan	0.014	0.118	0.012	0.110	-0.02
Gifted program	0.162	0.368	0.195	0.396	0.09*
Individualized Education Program	0.143	0.350	0.112	0.316	-0.09*
Multilingual learner	0.375	0.484	0.378	0.485	0.01
Math course attendance	0.762	0.190	0.783	0.180	0.11*
Any suspension	0.170	0.376	0.144	0.351	-0.07*
Any failing grade in a math course	0.566	0.496	0.540	0.498	-0.05*

Variable	Students in focal population		Students in analytic sample		Difference in means (standard deviation units)
	Mean (N = 18,238)	Standard deviation of mean	Mean (n = 14,260)	Standard deviation of mean	
English language arts proficiency benchmark (CMAS)	0.465	0.499	0.512	0.500	0.09*
Math proficiency benchmark (CMAS)	0.338	0.473	0.382	0.486	0.09*
9th grade academy	0.540	0.498	0.602	0.490	0.12*
Primary outcome					
Met Preliminary SAT 9 math proficiency benchmark	0.863	0.344	0.891	0.312	0.08*

* Difference in means larger than 0.05 standard deviations.

CMAS is Colorado Measures of Academic Success (standardized exams).

Note: This table presents means of student characteristics, experiences, and outcomes across two groups: the focal population of students the study aims to generalize to and the analytic sample of students the study findings are based on. Differences in means larger than 0.05 standard deviations are considered large and indicate that the focal population differed systematically from the analytic sample.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

One reason for missing outcome data on the PSAT is that not all students take the PSAT exam. Analyses were conducted to account for the varying PSAT response rates across students. Using these response rates as weights, the study weighted regressions by the inverse predicted probability of taking the PSAT (Wooldridge, 2002). The findings remained basically unchanged (table C4).

Table C4. Adjusting for students' probability of taking the Preliminary SAT (PSAT) 9 exam does not change study findings on factors strongly associated with meeting the PSAT 9 math proficiency benchmark, 2014/15-2022/23

Factor	Main specification Not controlling for the probability of taking the PSAT (n = 14,260)	Alternate specification controlling for the probability of taking the PSAT (n = 14,137)
Student characteristics		
Black	-0.097*† (0.014) [0.00]	-0.100*† (0.015) [0.00]
Hispanic	-0.058*† (0.010) [0.00]	-0.065*† (0.011) [0.00]
Middle school experiences		
Gifted program	0.125*† (0.011) [0.00]	0.134*† (0.010) [0.00]
Individualized Education Program	-0.059*† (0.009) [0.00]	-0.061*† (0.008) [0.00]
Any failing grade in a math course	-0.062*† (0.011) [0.00]	-0.058*† (0.011) [0.00]

Factor	Main specification Not controlling for the probability of taking the PSAT (n = 14,260)	Alternate specification controlling for the probability of taking the PSAT (n = 14,137)
English language arts proficiency benchmark (Colorado Measures of Academic Success, CMAS, exam)	0.142*† (0.014) [0.00]	0.133*† (0.013) [0.00]
Math proficiency benchmark (CMAS exam)	0.469*† (0.015) [0.00]	0.463*† (0.016) [0.00]
High school characteristics		
Above-average math proficiency (Preliminary SAT 9)	0.112*† (0.039) [0.01]	0.109*† (0.036) [0.00]
Above-average years of experience, all teachers	-0.042* (0.012) 0.00	-0.053*† (0.009) 0.00
Adjusted R-squared	0.58	0.59

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with grade 9 math success.

Note: This table shows the coefficients from ordinary least squares regressions that estimated the association between student characteristics and experiences and meeting the PSAT 9 math proficiency benchmark. Each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. For student characteristics, the study compared Black or Hispanic students with similar White students. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience (a one-unit change in a binary factor or a one-standard-deviation change in a continuous variable) was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. All models control for the factors listed in table A2 in appendix A.

Source: Authors' analysis based on 2014/15–2022/23, except 2019/20, administrative data from Denver Public Schools.

Characteristics of students' middle and high schools—including their teachers and peers—were strongly associated with grade 9 math success, particularly for Black students, Hispanic students, and students with an Individualized Education Program

The characteristics of a student's middle or high school, including the characteristics of the teachers in those schools, were associated with grade 9 math success. Middle or high school characteristics include the characteristics of a school (such as whether it was an innovation school); the students enrolled in a school (such as whether enrollment of NSLP-eligible students was above average); and the teachers working in that school (such as whether years of teaching experience were above average). The study includes factors that capture the characteristics of all teachers as well as math teachers. Although students are not linked directly to their classroom teachers in this study, teachers can influence students either directly or indirectly through other channels. For example, students and teachers can interact in nonclassroom settings (such as during extracurricular activities), and teachers can learn from one another (Jackson & Bruegmann, 2009; Opper, 2019; Qureshi, 2017). Most school and teacher characteristics are indicators capturing whether a school was above average (relative to the district average for school factors and the sample average for teacher factors) on that characteristic. (For a full list of school and teacher characteristics and their above-average thresholds, see table A2 in appendix A.)

Few middle or high school characteristics were strongly associated with grade 9 math success for grade 9 students overall at DPS (see table B1 in appendix B), but multiple school characteristics were strongly associated

with grade 9 math success for select student groups of interest. The discussion below highlights school-level factors that were associated with grade 9 math success for DPS' student groups of interest.

For Black students and students with an IEP, most factors strongly associated with grade 9 math success were school or teacher characteristics. For Black students, 8 of 12 factors that were strongly associated with grade 9 math success were school characteristics (see column 3 of table B1 in appendix B). Four were middle school characteristics (above-average percentages of teachers who were male, had advanced degrees, or were Black math teachers and above-average math proficiency rates), and four were high school characteristics (above-average percentages of teacher leaders, math teacher leaders, or math teachers with advanced degrees and above-average family engagement rates).

Of the school characteristics strongly associated with grade 9 math success for Black students, most captured the average characteristics of teachers in a school, including the strongest predictor of grade 9 math success for Black students. Specifically, Black students who attended a high school with an above-average percentage of teacher leaders were 10.5 percentage points less likely to succeed in grade 9 math than similar Black students who attended high schools with fewer teacher leaders. This should not suggest that the teacher leader program may not support Black students' math success. In fact, Black students who attended a high school with an above-average percentage of math teacher leaders (teacher leaders who also teach math) were 7.4 percentage points more likely to succeed in grade 9 math than other Black students. Given these contradictory associations, DPS may want to consider learning more about how high schools implement their teacher leader programs and how it might be associated with grade 9 math success.

For students with an IEP, 5 of 10 factors that were strongly associated with grade 9 math success were school characteristics (see column 4 of table B1 in appendix B). Four were middle school characteristics (above-average enrollment of NSLP-eligible students, being an innovation school, above-average math proficiency benchmark on the CMAS, and above-average family engagement rates); and one was a high school characteristic (hosting a newcomer center). In general, these findings confirm that the learning environment matters greatly for Black students and students with an IEP.

Additionally, for students with an IEP, attending an innovation middle school⁵ had the second strongest association with grade 9 math success of any factor.⁶ Students with an IEP who attended an innovation middle school were 10.5 percentage points less likely to succeed in grade 9 math than similar students with an IEP who did not attend an innovation middle school (see column 4 of table B1 in appendix B). While some Colorado districts use innovation status as a reform approach for low-performing schools, only about 30 percent of DPS innovation schools were in the lowest school performance categories (Priority Improvement or Turnaround) when they became innovation schools (Colorado Department of Education, 2019). About 15 percent of grade 9 students overall and 10 percent of students with an IEP in the sample attended one of six innovation middle schools. Attending an innovation high school was not associated with grade 9 math success for students with an IEP, but that could be because less than 5 percent of students with an IEP in the sample attended innovation high schools. Moreover, for students without an IEP, there is no association between attending an innovation school

⁵ Innovation schools are middle schools or high schools with community-created plans to improve student experiences and outcomes through innovative practices, such as extending the school day, holding extra teacher training days, and incorporating enrichment programs, such as afterschool Spanish programs or gardening classes (Denver Public Schools, 2024). Innovation schools are also allowed some autonomy to foster innovation, including greater control over staffing, scheduling, and budgeting and a pause on state accountability identification timelines, when applicable (Colorado Department of Education, 2024).

⁶ The factor with the strongest association with grade 9 math success for students with an IEP was having any suspension in middle school. See the Findings section of the main report for more information.

and grade 9 math success, suggesting that there may not be inherent problems with the innovation school approach.

The direction of some of the observed associations between school characteristics and grade 9 math success for Black students and students with an IEP is supported by the literature. For example, for both Black students and students with an IEP, the current study found that attending a middle school with above-average proficiency on the CMAS math standardized exam was strongly associated with grade 9 math success (see table B1 in appendix B). This finding parallels research showing that enrolling in a math course with higher-performing peers can increase test scores (Burke & Sass, 2011; Sacerdote, 2011).

Other associations were less clear and warrant further investigation. For example, Black students who attended middle schools with above-average percentages of Black math teachers were 5.5 percentage points more likely to be unsuccessful in grade 9 math than other similar Black students. This contradicts evidence that having a teacher of the same race is associated with improved math achievement for Black students (Egalite et al., 2015). However, DPS had few Black middle school math teachers during the study period. No middle school had more than four Black math teachers, and schools were considered to have an above-average percentage of Black math teachers if 3–5 percent of math teachers in the school were Black. With so few Black middle school math teachers, it is unlikely that their race had a meaningful relationship with math success, but the study findings might warrant additional attention from DPS to identify its cause.

For Hispanic students and multilingual learner students, attending a high school with an above-average suspension rate was strongly associated with being unsuccessful in grade 9 math. As discussed in the main report, receiving any suspension in middle school was strongly associated with being unsuccessful in grade 9 math for DPS students overall and for all student groups of interest. Additionally, for Hispanic students and multilingual learner students, attending a middle school with an above-average suspension rate was strongly associated with being unsuccessful in grade 9 math (average suspension rates were between 7.0 and 10.6 percent, depending on the study year). Specifically, Hispanic students who attended a middle school with an above-average suspension rate were 6.8 percentage points less likely to succeed in grade 9 math than Hispanic students who attended a middle school with a below-average suspension rate. Multilingual learner students who attended a middle school with an above-average suspension rate were 5.9 percentage points less likely to succeed in grade 9 math than multilingual learner students who attended a middle school with a below-average suspension rate. Attending a middle school with an above-average suspension rate was not strongly associated with grade 9 math success for other student groups of interest nor was attending a high school with above-average suspension rates.

There are multiple ways that schoolwide suspension rates could affect students' academic outcomes. For example, high suspension rates might occur when a school's learning environment is frequently disrupted by student misbehavior, which could impede other students' learning. Additionally, if students do not perceive suspensions as justified, a high suspension rate might weaken student engagement, which could lead to lower achievement.

DPS might consider examining whether and how school characteristics and the composition of the teaching staff in a school affects grade 9 math success. This study found that several school and teacher characteristics were strongly associated with students being successful or unsuccessful in grade 9 math. The findings also suggest that the composition of the teaching staff might be particularly influential for Black students and students with an IEP. DPS could conduct causal studies that link students to specific teachers to capture how teachers' characteristics, skills, and knowledge affect student outcomes, with a particular focus on Black students and students with an IEP.

Participating in the 9th grade academy was strongly associated with grade 9 math success for Black and Hispanic students

For Black and Hispanic students in DPS schools, participating in the 9th grade academy⁷ was strongly associated with grade 9 math success (figure C2). The optional 9th grade academy summer program was open to any student attending a school hosting the program, and approximately half of students in the sample attended the academy during the study period, with slightly lower participation rates among student groups of interest (table C5). Black students who participated in the 9th grade academy were 6.0 percentage points more likely to succeed in their grade 9 math course than similar Black students who did not participate. Hispanic students who participated were 5.7 percentage points more likely to succeed in their grade 9 math course than similar Hispanic students who did not participate. Participation was also associated with grade 9 math success for DPS students overall and for multilingual learner students, but not strongly.

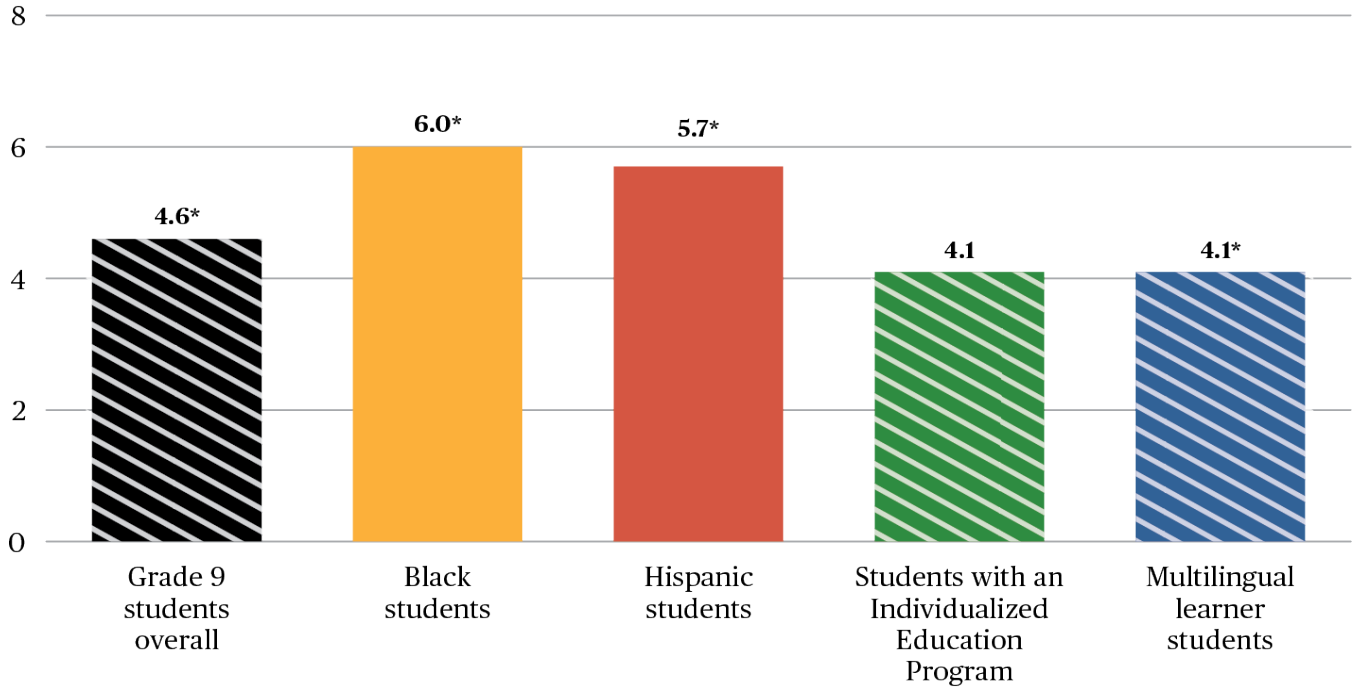
There are many possible reasons why students who participate in the 9th grade academy are more likely to succeed in grade 9 math, and further study is needed to understand which reasons might be driving these associations. For example, the 9th grade academy covered topics, such as building relationships with staff and explaining graduation requirements, that could have led to greater academic success in grade 9. The finding that attending the 9th grade academy was strongly associated with grade 9 math success only for Black and Hispanic students could suggest that students in those groups have greater baseline needs in areas aligned with these types of supports. Another possibility is that the program might have reduced summer learning loss, which could disproportionately affect Black and Hispanic students at DPS (Gierczyk and Hornby, 2023). However, because the program is opt-in and not offered in all schools, the students who attended the 9th grade academy could differ from other DPS students in unobserved ways, for example, by having a greater awareness of enrichment opportunities, which could lead those students to participate in multiple programs that this study did not observe.

Ultimately, this study was not able to determine whether participating in the 9th grade academy rather than some other unobserved factor was causing an increase in grade 9 math success. DPS might consider learning more about the impact of and mechanisms through which the 9th grade academy predicts grade 9 math success and the experiences of students who attend the program. These findings could inform efforts to bolster the program or identify meaningful approaches that could be applied in other ways throughout a student's middle school years. Because student groups of interest attended the 9th grade academy at below-average rates (see table C5), DPS might want to focus on increasing participation in the 9th grade academy for students in the student groups of interest and examining those students' experiences and whether participation supports success in grade 9 math.

⁷ The 9th grade academy is a summer orientation program to help rising grade 9 students prepare for high school by setting expectations and sharing strategies for a successful high school experience, such as understanding graduation requirements and building relationships with peers and staff.

Figure C2. Participating in the 9th grade academy was strongly associated with grade 9 math success for Black students and Hispanic students, 2014/15-2022/23

Difference in likelihood of grade 9 math success (percentage points)



* Significant at $p < .05$.

IEP is Individualized Education Program.

Note: This figure shows regression coefficients for participation in the 9th grade academy (a binary variable). The solid bars indicate a strong association with grade 9 math success, while the striped bars indicate no strong association. Each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who attended the 9th grade academy compared with otherwise similar students who did not. For student groups of interest, each coefficient represents the adjusted difference in the likelihood of grade 9 math success for students who attended the 9th grade academy compared with otherwise similar students in the same student group of interest who did not. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. Regression results are in table B1 in appendix B, and the list of all variables included in the regression is in table A2 in appendix A.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Table C5. Participation in the 9th grade academy among Denver Public Schools students overall and student groups of interest, 2014/15-2022/23

Students/group of interest	Percent of students participating
Grade 9 students overall	56
Black students	48
Hispanic students	46
Students with an Individualized Education Program	43
Multilingual learner students	44

Note: This table shows the proportion of each student group that participated in the 9th grade academy in the summer between grades 8 and 9.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Grade 9 student experiences were strongly associated with grade 9 math success, and in some cases, change associations between middle school experiences and grade 9 math success

Students' experiences during grade 9 matter for grade 9 math success. For example, a student's attendance rate or whether they received academic support programs in grade 9 can influence grade 9 course performance.

However, grade 9 experiences might also be influenced by middle school experiences. For example, a student's attendance rate during grade 9 might be influenced by the student's middle school experiences; a student who fails a course during middle school might become less engaged and attend school less during grade 9. To avoid obscuring the contribution of middle school factors to grade 9 math success and limit endogeneity bias, this study excluded some grade 9 student experiences from the main study specification (equation A1 in appendix A). Specifically, the study excluded the grade 9 academic supports, grade 9 academic achievement, and grade 9 school engagement factors listed in table C6.

To understand the association between these excluded experiences and grade 9 math success, the study team re-estimated equation A1 in appendix A, this time including the experiences listed in table C6. Column 1 of table C7 presents the results for the primary specification (equation A1), which excluded grade 9 experiences; column 2 adds grade 9 academic support factors; and column 3 adds grade 9 achievement and school engagement factors. Because grade 9 achievement is highly correlated with the outcome of grade 9 math success, the study team added these factors sequentially to first examine how receiving academic supports during grade 9 is associated with grade 9 math success.

The key takeaways of these analyses are as follows:

- Achievement and school engagement in grade 9 (column 3) mediate some associations between middle school experiences and grade 9 math success (associations shown in column 1). This means that after grade 9 achievement and school engagement factors were included, middle school achievement, middle school attendance, and middle school suspensions were no longer strongly associated with being successful in grade 9 math. This suggests that these middle school factors are associated with grade 9 math success through their influence on student experiences during grade 9. For example, a student with higher middle school attendance may build good attendance habits and, in turn, have high attendance in grade 9, which could then increase grade 9 math success. This sequence could explain why middle school attendance is no longer strongly associated with grade 9 math success once grade 9 attendance is taken into account.
- Having a suspension was strongly and consistently associated with being unsuccessful in grade 9 math across the board. Having any suspension in middle school had the strongest association in columns 1 and 2, and having any suspension in grade 9 had one of the strongest associations in column 3.
- Similarly, regardless of the model specification, attending a school with above-average Hispanic enrollment in grade 9 was strongly associated with being successful in grade 9 math, and attending a high school with a newcomer center was strongly associated with being unsuccessful in grade 9 math.
- In the fully specified model (which included all grade 9 factors), math course attendance was most strongly associated with grade 9 math success (column 3). This study did not have data on the criteria used to grade students and so could not determine whether math course attendance was counted toward a student's math course grade. If attendance was part of course evaluation criteria, that might partly explain why grade 9 math course attendance was most strongly associated with achieving grade 9 math success (passing grade 9 math course) and why it was not strongly associated with meeting the PSAT 9 math proficiency benchmark.⁸

⁸ Findings on the secondary outcomes are not presented but are available on request.

Table C6. Factor variable definitions for grade 9 factors excluded from the primary analysis

Factor	Definition
Academic supports	
504 plan	Ever had a 504 plan in grade 9. A 504 plan is a written accommodation plan that ensures that students with disabilities have equal access to education programs, services, and activities
Gifted program	Ever identified as gifted or talented in grade 9 and participated in the programming for students whose aptitude or competence in abilities, talents, and potential for accomplishment in one or more domains is so exceptional or developmentally advanced that they require special provisions to meet their education programming needs
Individualized Education Program (IEP)	Ever had an IEP in grade 9. An IEP is a legal, individualized plan that outlines the special education services and supports that a particular student with disability needs to succeed in school
Multilingual learner supports	Ever identified as in-service multilingual learner student, redesignated multilingual learner student, or exited multilingual learner status in grade 9
Academic achievement and school engagement	
Attendance rate	Proportion of school days that a student was marked present
Math course attendance rate	Proportion of days that a student was marked present in their main math course
Any suspension	Ever received any in-school or out-of-school suspension
Evidence-Based Reading and Writing proficiency Preliminary PSAT (EBRW PSAT)	Student met or exceeded the EBRW PSAT proficiency benchmark (at least 410)
Multiple out-of-school suspensions	Received two or more out-of-school suspensions

Note: All variables in the table are binary except for attendance rates, which are continuous.
Source: Authors' compilation.

Table C7. Including grade 9 experiences mediated many associations between middle school experiences and grade 9 math success, 2014/15-2022/23

Factor	(1) Main specification (<i>n</i> = 17,249)	(2) Grade 9 academic support added (<i>n</i> = 17,249)	(3) Grade 9 academic achievement and school engagement added (<i>n</i> = 17,249)
Middle school experiences			
Attendance rate	0.061*† (0.005) [0.00]	0.060*† (0.005) [0.00]	-0.001 (0.005) [0.83]
Any suspension	-0.106*† (0.007) [0.00]	-0.106*† (0.007) [0.00]	-0.038* (0.008) [0.00]
Any failing grade in a math course	-0.068*† (0.016) [0.00]	-0.068*† (0.016) [0.00]	-0.042* (0.013) [0.00]

Factor	(1) Main specification (n = 17,249)	(2) Grade 9 academic support added (n = 17,249)	(3) Grade 9 academic achievement and school engagement added (n = 17,249)
English language arts proficiency benchmark (Colorado Measures of Academic Success exam)	0.066*† (0.007) [0.00]	0.065*† (0.007) [0.00]	0.028* (0.005) [0.00]
High school experiences			
Above-average Hispanic student enrollment	0.067*† (0.023) [0.00]	0.067*† (0.023) [0.00]	0.092*† (0.032) [0.01]
Above-average National School Lunch Program eligibility	-0.094*† (0.044) [0.04]	-0.094*† (0.044) [0.04]	-0.080 (0.044) [0.08]
Newcomer center	-0.053*† (0.018) [0.01]	-0.053*† (0.018) [0.01]	-0.077*† (0.022) [0.00]
Attendance rate			0.059*† (0.012) [0.00]
Math course attendance rate			0.107*† (0.011) [0.00]
Any suspension			-0.103*† (0.014) [0.00]
Adjusted R-squared	0.23	0.23	0.36

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with grade 9 math success.

Note: This table shows coefficients from ordinary least squares regressions that estimated the association between student characteristics and experiences and grade 9 math success (defined as passing the main grade 9 course). Each coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. The table presents findings for the study's primary specification (column 1), which includes all factors in table A2 in appendix A and for a specification that adds grade 9 academic support variables (column 2) and one that adds grade 9 achievement and school engagement variables (column 3). The table presents results only for factors that were strongly associated with being successful in grade 9 math in at least one of the three models (statistically significant and with at least a 5 percentage point adjusted difference). Coefficients for continuous factors represent the change in the likelihood of success for a one-standard-deviation change in the factor, using the following standard deviations: student attendance rate, 0.146; math course attendance rate, 0.156; middle school student attendance rate, 0.094; and middle school math course attendance rate 0.187).

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

Factors found to be strongly associated, positively or negatively, with success in grade 9 math were similar when charter school students were included in the analytic sample

The analyses in this study focused on students in traditional, DPS-managed schools (noncharter schools). A large share of DPS students in the study data, however, attended charter schools for middle school, high school, or both (41 percent of sample students). This exploratory analysis identifies the characteristics and experiences that were strongly associated with being successful in grade 9 math when charter school students were included in the sample. That analysis found that the factors that were strongly associated with being successful in grade 9 math were similar to those when charter school students were excluded.

Having any suspension in middle school still had the strongest association, positive or negative, with success in grade 9 math when charter school students were included (table C8, column 2). Receiving any failing grade in a

middle school math course, meeting proficiency benchmarks on middle school English language arts standardized CMAS exams, and attending a school with a newcomer center in grade 9 remained strongly associated with success in grade 9 math. However, attending a high school with an above-average percentage of Hispanic students or attending a school with above-average percentages of students who are eligible for the NSLP were no longer strongly associated with grade 9 math success when charter school students were included in the sample.

For the secondary outcome, meeting PSAT 9 proficiency benchmarks, factors most strongly associated with meeting PSAT 9 math proficiency were similar when charter school students were included and when they were not (table C9).

Table C8. Factors strongly associated with grade 9 math success were similar after students in charter schools were added to the sample, 2014/15–2022/23

Factor	(1) Main specification, excluding charter school students (<i>n</i> = 17,249)	(2) Specification including charter school students (<i>n</i> = 29,277)
High school characteristics		
Above-average Hispanic student enrollment	0.067*† (0.023) [0.00]	0.035 (0.018) [0.05]
Above-average National School Lunch Program eligibility	-0.094*† (0.044) [0.04]	-0.037* (0.017) [0.03]
Newcomer center	-0.053*† (0.018) [0.01]	-0.061*† (0.019) [0.00]
Middle school experiences		
Attendance rate	0.061*† (0.005) [0.00]	0.060*† (0.005) 0.00
Any suspension	-0.106*† (0.007) [0.00]	-0.100*† (0.006) [0.00]
Any failing grade in a math course	-0.068*† (0.016) [0.00]	-0.070*† (0.011) [0.00]
English language arts proficiency benchmark (Colorado Measures of Academic Success exam)	0.066*† (0.007) [0.00]	0.063*† (0.007) 0.00
Adjusted R-squared	0.23	0.23

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with grade 9 math success.

Note: This table shows regression coefficients for the seven factors that were strongly associated with being successful in grade 9 math for Denver Public Schools students in analyses of samples that excluded charter schools and those that included them. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. Each regression coefficient represents the adjusted difference (after other factors are controlled for) in the likelihood of grade 9 math success for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. Both models include all factors and controls listed in table A2 in appendix A.

Table C9. Factors strongly associated with meeting Preliminary SAT 9 math proficiency were similar after students in charter schools were added to the sample, 2014/15-2022/23

Factor	(1) Main specification, excluding charter school students (<i>n</i> = 14,260)	(2) Specification including charter school students (<i>n</i> = 24,736)
Student characteristics		
Black	-0.097*† (0.014) [0.00]	-0.084*† (0.010) [0.00]
Hispanic	-0.058*† (0.010) [0.00]	-0.058*† (0.008) [0.00]
Middle school experiences		
Gifted program, middle school	0.125*† (0.011) [0.00]	0.112*† (0.008) [0.00]
Individualized Education Program, middle school	-0.059*† (0.009) [0.00]	-0.072*† (0.007) [0.00]
Any failing grade in a middle school math course	-0.062*† (0.011) [0.00]	-0.070*† (0.009) [0.00]
English language arts proficiency benchmark (CMAS exam)	0.142*† (0.014) [0.00]	0.155*† (0.012) [0.00]
Math proficiency benchmark (Colorado Measures of Academic Success, CMAS, exam)	0.469*† (0.015) [0.00]	0.453*† (0.013) [0.00]
High school characteristics		
Attended a high school with above-average proficiency on Preliminary SAT 9 math exam	0.112*† (0.039) [0.01]	0.135*† (0.011) [0.00]
Middle school characteristics		
Attended a high school with above-average teacher years of experience	-0.042* (0.012) 0.00	-0.067*† (0.012) 0.00
Adjusted R-squared	0.58	0.55

* Significant at $p < .05$. Robust standard errors clustered at the school level are shown in parentheses, and p -values are shown in brackets.

† Strong association with meeting the PSAT 9 math proficiency benchmark.

Note: This table shows the regression coefficients for the nine factors that were strongly associated with meeting the PSAT 9 math proficiency benchmark for Denver Public Schools students in analyses of samples that excluded charter schools and those that included them. Each regression coefficient represents the adjusted difference in the likelihood of PSAT 9 math proficiency for students who had the characteristic or experience (one unit higher for binary factors and one standard deviation higher for continuous factors) compared with otherwise similar students who did not. The study considered an association to be strong if it was statistically significant at the 95 percent confidence level and if having the characteristic or experience was associated with at least a 5 percentage point difference in the likelihood of grade 9 math success. Both models include all factors and controls listed in table A2 in appendix A.

Source: Authors' analysis based on 2014/15-2022/23, except 2019/20, administrative data from Denver Public Schools.

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