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Closing the Achievement Gap in Math:

The Long-Term Effects of Eighth-Grade Algebra

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Educational policies have traditionally limited eighth-grade algebra to selected students who have demonstrated readiness or who have above-average mathematical ability. However, recent changes in curricular design and more stringent state standards have resulted in increased access to the study of algebra in eighth grade among larger populations. Standards-driven mathematics curricular reform has improved the skill-based infrastructure in the middle grades, opening eighth-grade algebra to more students. This development may bestow long-term benefits in terms of mathematics literacy and attainment among larger populations. The study of algebra acts as the gatekeeper to more advanced courses in both mathematics and science. Therefore, one hypothesis is that providing eighth-grade algebra to all students may enhance mathematics literacy across all populations.

This study examined the long-term effects of completing algebra in eighth grade in one large school district. The district had recently modified its longstanding mathematics curriculum to provide eighth-grade algebra classes for greater numbers of students throughout the district. The driving force for the cur-

summary

Recent changes in national and state mathematics standards have increased the level of algebraic thinking taught in younger grades. These changes have prompted more inclusive curriculum designs that open the opportunity to enroll in advanced mathematics courses at younger ages. Of particular interest to this study is the access to eighth-grade algebra, once traditionally reserved for select populations. This study examined long-term academic outcomes for students who did or did not enroll in eighth-grade algebra in one district that implemented an initiative to increase access. The outcomes of students with similar ability, as measured by preassessment in seventh grade, were compared. The groups performed similarly on end-of-course exams in high school math and the mathematics section of the SAT I. However, students who completed algebra in the eighth grade stayed in the mathematics pipeline longer and attended college at greater rates than those who did not. Because of the sequential nature of mathematics course work, students taking algebra at an earlier age have the opportunity to enroll in more advanced courses in the future. Results suggest the need for further exploration of how to provide access and promote enrollment in eighth-grade algebra for students who demonstrate readiness.

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ricular reform was the state mandate to raise proficiency levels among diverse populations. This type of mandate often results in districts' devoting a large share of their limited resources to bringing students from basic to proficient levels on state accountability measures (Gallagher, 2004). The district in this study sought to raise proficiency levels among students by moving beyond basic proficiency and offering a course traditionally regarded as rigorous and appropriate only for students with the potential to study more advanced content.

This study first sought to determine the equity and the effects of the reform and then to explore the implications of the more inclusive policy. This study involved a longitudinal follow-up analysis of an original dataset (Spielhagen, 2006), which revealed benefits in the number and type of math courses studied after eighth grade. That original analysis also raised questions about the ways in which students gained entrance into eighth-grade algebra and the effects of eighth-grade algebra on future academic activity, specifically college attendance.

Background

Mathematics Standards Reform

In the 1990s, the standards reform movement spearheaded by the National Council of Teachers of Mathematics (NCTM, 1989) led schools to examine longstanding curricular policies that restricted early (i.e., eighth grade) study of algebra to selected students while withholding it from others on the basis of readiness. At the same time, the NCTM also advised schools to increase the rigor of mathematics instruction in the elementary and intermediate grades, as well as middle school mathematics classes before eighth grade, in order to create an infrastructure of readiness among the student population and to open the doors to algebra study for more students in eighth grade. Five years later, the National Center of Education Statistics (NCES, 1994) reported that "effective" middle schools offered algebra to eighth-grade students. "Effectiveness" in that study referred to the success of students on the National Assessment of Educational Progress (NAEP) measures of achievement in mathematics. In fact, subsequently, the NCES (2001) reported that the NAEP data indicated a clear relationship between eighth-grade students' scores and their current mathematics course. Smith (1996) had also concluded that "early access to algebra has a sustained positive effect on students, leading to more exposure to advanced mathematics curriculum and, in turn, higher mathematics performance by the end of high school" (p. 148).

The study of algebra in eighth grade by all students could potentially address the issue of mathematics literacy in the United States and result in greater numbers of students enrolled in advanced mathematics and science courses. An examination of the Trends in International Mathematics and Science Study (TIMSS; NCES, 1999) and the Third International Mathematics and Science Study–Repeat (TIMSS-R) attacked traditional mathematics curricula in the United States and concluded that "The 8th-grade mathematics curriculum in the U.S. seems comparable to the average 7th-grade curriculum for other participating countries, putting U.S. students a full year behind their global counterparts at age thirteen" (Greene, Herman, & Haury, 2000, p. 2). In that same year, the National Council of Teachers of Mathematics (2000) issued new standards influenced by concerns about the performance of U.S. students in the international arena.

Assouline and Lupkowski-Shoplik (2005) warned that the original standards-based curriculum proposed by NCTM in 1989 was detrimental to mathematically talented students because teachers were discouraged from planning differentiated and challenging curriculum. They concluded that the revised version of the national mathematics standards (NCTM, 2000) does in fact introduce rigor and challenge for all students throughout the middle school years. However, they emphasized that teachers must be prepared to differentiate curriculum for mathematically talented students in eighth grade.

Cogan, Schmidt, and Wiley (2001) focused policymakers on strengthening mathematics literacy initiatives, particularly in the nation's middle schools, as a means of providing the basis for more rigorous work in high school. Schmidt (2003) further decried the U.S. pattern of little or no gain from 8th to 12th grade as the result of a "middle school curriculum lacking coherence, with little rigor or extreme variability in learning opportunities as a consequence of tracking policies" (p. 278). These policies frequently result in a "dumbing down" of curriculum for many students in a typical middle school, especially among underrepresented populations. VanTassel-Baska (2000) recommended that curricular policy initiatives should take into account the needs of high-ability learners but should also encourage underrepresented groups to access rigorous courses. Therefore, algebra study by greater numbers of eighth-grade students may improve overall mathematics literacy among the larger population.

The Promise of Algebra

Eighth-grade algebra provides both rigor and opportunity, while potentially enhancing mathematics literacy across the student population. If education policymakers consider early access to algebra as a means of increasing mathematics literacy, they must also provide equitable access to that literacy. Therefore, research must continue to inform policymakers of the benefits of early access to algebra, the availability of eighth-grade algebra to all students, and the implications of algebra study among diverse populations.

Several studies have chronicled the correlation between students' prior achievement, the timing of mathematics course-taking, and performance on state standardized tests. NAEP (NCES, 2001) data show that students who study algebra in the eighth or even seventh grade do as well as or better on state standardized tests than their peers who have not studied algebra. Students who were studying pre-algebra performed better in 2000 than students taking the nonalgebraic eighth-grade math (270 versus 264 out of 500), and students taking first-year algebra do better than those taking pre-algebra (301 versus 270). Prior performance may have provided entry into algebra or even pre-algebra in eighth grade and may explain subsequent performance on state standardized tests.

Recent curricular reforms proposed by the NCTM (2000) address the potential efficacy of algebra for all students. However, the NCTM does not advocate the study of algebra in eighth grade by all students. The NCTM does emphasize the development and study of algebraic concepts starting in prekindergarten and continuing throughout elementary and secondary school. The incorporation of algebraic skills in the primary and intermediate grades may create a base for the study of algebra in eighth grade. The study of algebra enhances cognitive skills while serving as a gatekeeper to more advanced academic courses and enhanced opportunities after high school. Gamoran and Hannigan (2000) found that "whether cognitive differences among students lead to variation in learning rates, or not, taking algebra is still a good idea for everyone" (p. 250). Moreover, Smith (1996) maintained that "the question of whether schools should provide advanced coursework to only a select few students remains at the center of this policy debate" (p. 149). Hallinan (2000) reported that her findings from a longitudinal study of high school students suggest that most students, with few exceptions, generally attain higher achievement in a higher level group.

Because algebra is the gatekeeper course to advanced study in both mathematics and science (Smith, 1996), offering algebra in eighth grade to all students can begin to address the decline of achievement in high schools in the U.S. The sequential nature of mathematics precludes students from studying calculus in high school unless they study algebra in eighth grade (Assouline & Lupkowski-Shoplik, 2005). Students who wait until 9th grade to begin the study of algebra must double-up on mathematics courses if they want to take calculus in 12th grade. Having studied calculus in high school, students are then better prepared for taking mathematics courses in college. Regardless of their long-term plans, students might well benefit from the nature of the content of more advanced mathematics courses in high school (Gamoran & Hannigan, 2000; Smith).

This question of appropriate rigor in learning experiences underlies recent standards-based initiatives throughout the states. In a recent analysis of state high school graduation requirements, Schiller and Muller (2003) noted that "the mathematics courses students take in high school affect their academic achievement and their admission to competitive postsecondary schools and professional programs" (p. 300). However, if greater numbers of students can and should study algebra in eighth grade, then provisions must be made for students who can move beyond this newly designated mastery goal.

Methods

These prior studies served as the rationale for an examination of one district's recent efforts to open the gates to advanced mathematics instruction to a greater portion of the student population while providing appropriate rigor for all students. To gain a baseline understanding of mathematic reform efforts at the ground level, this study addressed the problem of achievement gaps among underrepresented populations in a large school district (n = 60,000) in a southeastern state by examining the long-term effects of early access to the study of algebra. This countywide district borders a large southern city and has 36 elementary schools, 11 middle schools, and 11 high schools. The schools vary in diversity and socioeconomic composition across the district. Schools are located in varying neighborhoods, from urban-style enclaves to upper middle class housing developments to widely spaced homes and housing trailers in rural settings. Eighth-grade algebra was offered to selected students in each of the middle schools. In these eighth-grade algebra classes, all students used the same textbooks and followed the same curriculum and district-designed pacing guides.

Three research questions guided this research study. First, what was the demographic composition of the eighth-grade algebra class? Second, to what extent were the selection criteria for this course implemented in an equitable manner across all populations in the district? Finally, to what extent were there long-term advantages experienced by students who had studied algebra in eighth grade?

This study involved a longitudinal follow-up to prior research (Spielhagen, 2006) that revealed an overlap of entrance credentials and inequity in the outcomes among students in this district. Simply put, the data revealed that some students with the stated entrance credentials were not selected for eighth-grade algebra. This group of students, subsequently labeled the *overlap group* became the subject of more detailed analysis and the impetus for examination of the longitudinal implications of having studied algebra in eighth grade.

Data analysis in this study involved a sample of students (n = 2,634) who were in the 2004 high school graduation class and who had been divided into two groups: those who had been selected for algebra in eighth grade and those who, by default of not being selected, studied algebra in ninth grade. However, there is an inherent selection bias that likely affected the mathematics performance of the eighth-grade algebra students. Students with higher math ability or higher prior math achievement were more likely to gain entrance into algebra in eighth grade. Therefore, when possible, analyses were conducted comparing subsets of students who had similar prior math ability and achievement. Examining the groups that overlapped in terms of their entrance credentials provided the basis for a critical examination of the educational paths taken by students after their eighth-grade mathematics experience and of the long-term effects of early algebra instruction.

Examination of the data proceeded logically from descriptive to comparative analyses. First, descriptive statistics examined the characteristics of the two pools within the dataset. Then, logistic regression examined the interplay of the background variables to determine the degree to which they interacted to predict membership in either group. Individual school populations were also scrutinized to determine any relationship between school demographics and the opportunity for algebra in eighth grade. Finally, the long-term effects of having studied algebra in eighth grade were explored using both descriptive statistics and ANOVAs through three outcome variables: mathematics course-taking after 8th grade; outcome tests of achievement, including mathematics SAT scores in 11th grade; and college attendance after graduation from high school.

Results

Who Studied Algebra in Eighth Grade?

Longstanding district policy involved a complex nomination system that involved three universally employed criteria, working in tangent with each other: (1) prior performance, as indicated by grades earned in seventh-grade mathematics classes, (2) scores on the Stanford 9 Mathematics Test administered at the end of seventh grade, and (3) teacher nomination. In some of the middle schools, teacher nominations were supported by students' scores on a locally designed algebra prognosis test, but this was not a universal criterion across the district. Moreover, the opportunity to be selected for eighth-grade algebra was usually reserved for students already enrolled in honors mathematics classes. While students in nonhonors classes could be selected for algebra in eighth grade, the large majority of those in eighth-grade algebra came from the honors classes.

In the sample of students in this study, 45.6% (1,200) studied algebra in eighth grade, and 54.4% (1,434) studied it in ninth grade (the default option de facto not being selected for eighth-grade algebra.). More girls than boys took eighth-grade algebra, both in the total population and in each ethnic group. Moreover, descriptive statistics further revealed that selection for eighth-grade algebra was disproportionate by ethnicity according to percentages of the two groups on the total population. Black students comprised 20% of the total population. However, they comprised less than 10% overall of the population in eighth-

Table 1

Total Population:
Algebra Experience by Gender and Ethnicity

Grade 8 Students		Algebra in Grade 8			Grade 8 Math		
	Total Population $N = 2{,}634$	Total $n = 1{,}200$	Male $n = 592$	Female $n = 608$	Total $n = 1{,}434$	Male $n = 738$	Female $n = 696$
Native American	$n = 3$ (<1%)	$n = 1$ (<1 %)	$n = 1$ (<1 %)	$n = 0$ (0 %)	$n = 2$ (<1%)	$n = 0$ (0%)	$n = 2$ (<1%)
Asian/Pacific Island	$n = 64$ (3%)	$n = 39$ (3%)	$n = 20$ (3.3%)	$n = 19$ (2.6%)	$n = 25$ (1.7%)	$n = 19$ (2.6%)	$n = 6$ (.86%)
Black, not Hispanic	$n = 458$ (20%)	$n = 125$ (10%)	$n = 53$ (8.9%)	$n = 72$ (11.8 %)	$n = 333$ (23.2%)	$n = 145$ (19.6%)	$n = 188$ (27%)
Hispanic	$n = 32$ (1%)	$n = 11$ (1.5 %)	$n = 9$ (1.5 %)	$n = 2$ (<1%)	$n = 21$ (1.5%)	$n = 14$ (1.9%)	$n = 7$ (1%)
Caucasian/ Other	$n = 2{,}077$ (75%)	$n = 1{,}024$ (85.3%0	$n = 509$ (85.9%)	$n = 515$ (84.7%)	$n = 1{,}053$ (73.4%)	$n = 560$ (76%)	$n = 493$ (71%)

***Note*. Percentages derive from data in the columns.**

grade algebra and 30% of the total ninth-grade algebra population. Similarly disparate percentages were noted for females in this dataset. Table 1 displays algebra experience by gender and ethnicity.

Logistic regression examined how background variables predicted placement into each of the two treatment groups. Table 2 contains the results of this logistic regression. The other variables were derived from designations related to the school experiences of the students: Stanford test scores used for selection as a pretest, local grades in seventh-grade math, and identification as gifted.

Not surprisingly, after controlling for the other variables in the model, having been identified as gifted was the strongest variable in predicting selection for eighth-grade algebra, but that variable also had the largest confidence interval, perhaps an indication of the inconsistency in the implementation of the identification process for involvement in the district's gifted program. In some, but not all, of the elementary schools, teachers nom-

Table 2

Composition of Grade 8 Algebra by Prior Performance, Parent Education, and Race Predicting Performance by Algebra Group

Algebra: Grade 8	Odds Ratio	*SE*	*z*	*p*	95% conf. interval	
Grade 7						
Local Math Grade	3.65	.31	15.19	<.001	3.09	4.33
Stanford Math						
Grade 8 Pretest	1.06	<.01	21.82	<.001	1.06	1.07
Father's Schooling	1.03	.01	2.43	.015	1.01	1.06
Mother's Schooling	.99	.01	-.51	.613	.97	1.02
Identified Gifted	5.73	2.19	4.57	<.001	2.71	12.13
Race						
Native American	.62	.54	-.54	.588	.11	3.42
Asian	1.41	.31	1.54	.122	.91	2.17
Black/Not Hispanic	.31	.03	-12.17	<.001	.26	.37
Hispanic	.43	.13	-2.73	.006	.23	.79

Note. Logit estimates: $N = 2634$. $p < .001$. Pseudo $R^2 = 0.5362$.

inated students as early as third grade for special enrichment classes. Sometimes, but not universally, those nominations were supported by standardized (Stanford 9) scores. The percentage of students who were identified as gifted varied by school, and the schools themselves varied in demographic composition and socioeconomic status. Similarly, after controlling for the other variables in the model, a one-point increase in seventh-grade math grades (on a traditional 4-point scale, with $A = 4$, $B = 3$, $C = 2$, $D = 1$) was associated with being more than three times more likely to take algebra in eighth grade. Moreover, each additional percentage point on the Stanford Grade 8 pretest was associated with a 6% increase in the likelihood of taking eighth-grade algebra.

In this logistic regression, after controlling for the other variables in the model, ethnicity was statistically significant, predicting the involvement of Black, non-Hispanic students in the eighth-grade algebra classes.

Moreover, additional examination of data deriving from free and reduced lunch percentages (see Table 3) revealed a negative relationship between the socioeconomic status of each school's population and the number of students studying algebra in eighth grade. In other words, the higher the percentage of students with free and reduced lunch, the lower the number of students in eighth-grade algebra. The lower the percentage of students with free and reduced lunch, the higher the number of students identified as gifted, a label that was not universally defined across the district and one that was a general label, not specific in nature. However, selection for the algebra classes implied mathematical talent. This finding accentuated the possibility of achievement gaps related to the algebra program in this district despite efforts on the part of the district to administer its policy equitably.

Table 3 also shows that in some of the middle schools, very small numbers of students in the eighth grade studied geometry. These numbers, although they are very small, suggest that there is no defined pattern of course delivery across the district. The highest number of students taking geometry in eighth grade (n = 22) was in the school that was ranked seventh in socioeconomic status, according to free and reduced lunch percentages. The next two highest numbers (n = 17 and n = 16 students) were in the schools with the highest SES in the district.

Further quantitative analysis using ANOVAs examined the achievement of students in each group by comparing the perfor-

Table 3

Total Population: Course-Taking Patterns by Schools

School No.	Percent Free/Reduced Lunch	Number Identified Gifted Grade 8	Total in Grade 8	Enrolled in Grade 8 Math	Enrolled in Grade 8 Algebra	Ratio Enrolled in Grade 8 Algebra vs. Grade 8 Math	Enrolled in Geometry in Grade 8
Total			3,694	2,197	1,426	1.54	71
1	.1%	61	406	182	207	.88	17
2	.2%	63	367	178	173	1.03	16
3	.6%	55	390	165	217	.76	8
4	.9%	29	457	310	143	2.17	4
5	11.8%	14	229	136	92	1.48	1
6	18.4%	24	314	191	123	1.55	0
7	18.9%	71	355	194	139	1.40	22
8	19.4%	21	365	257	108	2.38	0
9	22.4%	24	332	209	122	1.71	1
10	27.3%	7	166	130	36	3.61	0
11	40%	8	313	245	66	3.73	2
Mean				185	120	1.54	

***Note*. This data was gathered 4 years after initial analysis. Total population in this dataset varies from that of the original set.**

Table 4

Total Population:
ANOVAS of Outcome Scores of Grade 8 Algebra Students (n = 1,200) versus Grade 8 Math Students (n = 1,434)

Assessment Measures	Grade 8 Algebra Students Mean (*SD*)	Grade 8 Math 8 Students Mean (*SD*)	ANOVA *F*-score	*p*	Effect Size Cohen's *d*
Stanford Math Test Pre-Eighth Grade	70.4 (27.4)	44.3 (26.8)	633	< .0001	.96
Grade 8 State Math Test Post-Eighth Grade	469.8 (74.3)	408.3 (56.2)	640	< .0001	.94
State Algebra Test Post-Algebra Class	446.4 (58.2)	410.9 (28.8)	60.7	< .0001	.82

mance of each treatment group on two state standardized tests (Comprehensive Grade 8 Mathematics and Algebra). Stanford 9 Mathematics Tests, administered in the spring of each school year, served as an entrance criterion for studying algebra in eighth grade, as well as a measure of achievement in the eighth-grade year. Table 4 shows the achievement patterns of the total student population, grouped by their eighth-grade math course, on all three tests: the Stanford 9 pretest (administered in seventh grade) and the two state tests. All students took the grade-eight state test at the end of their eighth-grade year. Students took the state algebra test at the end of their algebra course, in either eighth or ninth grade. When examining the total sample, the students who were enrolled in algebra exhibited higher achievement on the Stanford pretest, the eighth-grade state test, and the state algebra test than the students who were in eighth-grade math.

Mathematics Courses in High School

When comparing the total student population (initial n = 3,736; final sample n = 2,903), students who took eighth-grade algebra stayed in the mathematics pipeline longer and took more advanced mathematics courses than students who took eighth-grade math. The latter finding makes sense because of the sequential nature of mathematics courses. Without eighth-grade algebra, it is not likely that a student will study calculus in high school. However, there was substantial attrition in the number of mathematics courses students took after eighth grade. This, of course, can be attributed to many variables, including the varying aptitudes of students in the two treatment groups.

Table 5 contains the breakdown of course-taking in 11th grade among all students in the data set, according to the mathematics course they took in 8th grade. Participation in the early access eighth-grade algebra course led to further attainment in the quantity and quality of mathematics courses taken after the algebra experience. The state's minimum requirement for mathematics is 2 years of high school mathematics, including algebra. Most students followed the traditional sequence of algebra, geometry, and then Algebra 2. Students in the eighth-grade algebra class necessarily had a head start on this sequence. This early advantage affected the type of courses taken and the likelihood of taking additional mathematics courses, because they could ultimately advance to calculus in 12th grade. Students who waited to study algebra in ninth grade often then took Algebra 2 as their final mathematics course in high school.

Outcome Measures of Achievement

The question of equity came into sharper focus when close examination of the Stanford pretest scores in the second and third quartile revealed an overlap among the entrance credentials of those who were selected for eighth-grade algebra and those who were not. Even though the Stanford pretest scores were used to select students for algebra in eighth grade, not all students who had the qualifying Stanford scores were selected for algebra in eighth grade. Some students remained in regular eighth-grade math, even though they had the entrance credential for eighth-grade algebra. These students allow us to com-

Table 5

Total Population:
Group Membership and Attainment in Grade 11

	Grade 8 Algebra Original n = 1,460		Grade 8 Math 8 Original n = 2,276	
Grade 11 Math Course	n	%	n	%
Consumer Math	0	0	4	0.2%
Foundations of Algebra	1	0.1%	36	2%
Applied Algebra/Foundations of Geometry	2	0.1%	82	4%
Applied Geometry	6	0.4%	189	11%
Algebra	1	0.1%	49	3%
Algebra Modified	0	0	3	0.2%
Geometry	9	0.7%	222	13%
Algebra 2	179	15%	1,035	62%
Enriched Algebra 2	17	1%	14	1%
Algebra 2/Trigonometry	2	0.1%	15	1%
Trigonometry/Advanced Algebra	125	10%	2	1%
Trigonometry/Mathematics Analysis	506	41%	12	0.7%
Mathematics Analysis	313	26%	4	0.2%
High School Calculus	0	0	1	0.1%
AP Calculus AB	0	0	1	0.1%
Probability/Statistics	5	0.4%	0	0
SAT Mathematics Preparation	4	0.3%	6	0.3%
AP Statistics	4	0.3%	0	0
Integrated Pre-Calculus 3	48	4%	3	0.17%
Mathematics Models	2	0.1%	1	0.1%
Total	1,224	83.8%	1,679	73.8%

Note. **This data was gathered 4 years after initial analysis. Total population in this dataset varies from that of the original set.**

pare the math outcomes of two groups of students with similar initial math performance on the same measure of achievement. This representative sample was drawn from the second and third quartiles of the Stanford pretest scores. It contained approximately 10% (n = 264) of the total population and was evenly

Table 6

Overlap Group: Selected demographics

	Gender		Ethnicity	
	Male	Female	White	Black
Grade 8 Math 8 (n = 136)	57%	43%	17%	83%
Grade 8 Algebra (n = 128)	31%	69%	76%	24%

divided into two groups, those who had eighth-grade algebra and those who did not.

Therefore, the next stage of analysis explored the long-term implications of access to eighth-grade algebra through three outcome variables: mathematics course-taking after eighth grade, scores on the mathematics section of the SAT I with specific examination of the group whose pretest scores overlapped, and college attendance after graduation from high school. Table 6 contains the demographic information for the students in this group.

A simple t test revealed that the two groups were equivalent in their entrance credentials for eighth-grade algebra and on their scores on the state algebra test, with $p > .05$ for each measure. Three years later, examination of the scores on the mathematics section of the SAT I for both groups revealed additional similarities between the scores of those who took algebra in eighth grade and those who had not. Table 7 contains their scores on four external tests of achievement: their Stanford pretest scores, the state Mathematics 8 Test, the state algebra test, and their SAT scores in Grade 11. There were no statistically significant differences between the two overlapping groups on any of the math achievement tests.

College Attendance

Not surprisingly, examination of the total population revealed that students who had studied algebra in eighth grade ultimately attended college in greater numbers than their peers who studied regular mathematics in eighth grade. Table 8 illustrates the breakout of college attendance in terms of mathematics experience in eighth grade, in both the total population and in the overlap group.

Table 7

Overlap Group:
Outcome Measures—Mean Scores and Standard Deviations

	Stanford Math Pretest Total Score	Stanford Math Pretest Problem Solving	Stanford Math Pretest Procedures	State Math 8 Test	State Algebra Test	SAT 1 MATH Score in Grade 11
Grade 8 Math	69.0 (19.3)	77.2 (20.6)	52.2 (16.8)	438.6 (45.9)	428.0 (35.4)	488.1 (58.4)
Grade 8 Algebra	69.4 (19.1)	78.0 (20.7)	51.8 (16.6)	443.4 (35.1)	433.8 (44.3)	493.5 (54.9)
t	.074	.137	-.095	-.445	-.541	.283
p	.941	.892	.924	.658	.591	.779
Cohen's *d*	.020	.039	.024	.119	.146	.095
df	262	262	262	262	262	228

Table 8

Total Population and Overlap Group:
College Attendance Among Students in Grade 8 Math
Compared to Students in Grade 8 Algebra

College Attendance	Grade 8 Math 8 Total Group	Grade 8 Algebra Total Group	Grade 8 Math 8 Overlap Group	Grade 8 Algebra Overlap Group
No College	31%	21%	51%	41%
2-Year College	23%	17%	15%	14%
4-Year College	46%	62%	34%	45%

Students in the overlap group showed lower college attendance rates than the total population regardless of their mathematics placement in eighth grade. Moreover, the students in both sections of the overlap group attended 2-year college at approximately the same rate, while the margin between the two groups in 4-year college attendance was smaller than in the general population. Tables 9 and 10 present the results of the

Table 9

College Attendance Patterns by Eighth-Grade Math Participation for the Whole Sample

	Math Class		
	Math 8	Algebra 8	Total
No College			
Count	424	247	671
Expected Count	356.5	314.5	671.0
% Within Math Class	31.1%	20.5%	26.1%
2-Year College			
Count	319	210	529
Expected Count	281.1	247.9	529.0
% Within Math Class	23.4%	17.4%	20.6%
4-Year College			
Count	622	747	1,369
Expected Count	727.4	641.6	1,369.0
% Within Math Class	45.6%	62.0%	53.3%

Note. Chi-square = 70.75 with 2 *df*, $p < .001$. Cramer's $V = .166$.

chi-square tests of independence, which tested the association between eighth-grade math coursework and subsequent college enrollment. While the chi-square test of independence was statistically significant for the full sample, it was not statistically significant for the overlap sample. The Cramer's *V* values for these chi-square analyses (.166 for the full sample and .122 for the overlap sample) suggest a small association between eighth-grade math coursework and subsequent educational attainment.

Discussion

This study examined the effects of increased access to eighth-grade algebra in terms of long-term achievement and attainment. This district did not provide algebra to all students in eighth grade, but instead opened the course to greater numbers of students in an attempt to increase mathematics literacy

Table 10

College Attendance Patterns by Eighth-Grade Math Participation for the Overlapping Groups

	Math Class		
	Math 8	Algebra 8	Total
No College			
Count	70	52	122
Expected Count	62.8	59.2	122.0
% Within Math Class	51.5%	40.6%	46.2%
2-Year College			
Count	20	18	38
Expected Count	19.6	18.4	38.0
% Within Math Class	14.7%	14.1%	14.4%
4-Year College			
Count	46	58	104
Expected Count	53.6	50.4	104.0
% Within Math Class	33.8%	45.3%	39.4%

Note. Chi-square = 3.91 with 2 *df*, $p = .14$. Cramer's $V = .122$.

across diverse student populations, while maintaining a modified selection policy. In this study, restricting access to eighth-grade algebra made no significant difference in the outcome performance of the students on the state algebra tests, whereas studying algebra in eighth grade yielded tangible benefits in terms of additional mathematics courses taken and subsequent college attendance.

This study had two important limitations. The first limitation derives from the origin of the data sample, which was drawn from only one district. These results cannot be generalized beyond this school district of 60,000 students. In addition, the data was drawn over a period of 4 years. As a result, follow-up data analysis involved different total populations, resulting from the ways in which data was collected in the 11 high schools and 11 middle schools in the district. However, because the practice of limiting access to eighth-grade algebra has been common in schools in the U.S., future research should replicate this study in other similar environments to explore whether the same results will ensue.

The second limitation involved the lack of information regarding the content of the algebra courses. No additional information was available at the time of this study about the actual content and the type of study prescribed in the algebra courses other than the fact that the curriculum was uniform throughout the schools. The district officials self-reported that all classes use the same textbooks and that the curriculum addressed NCTM standards. The district also had detailed pacing guides, suggesting that each algebra teacher taught the same topics in the same sequence.

When schools districts address the needs of diverse populations, they must strive to maintain equitable delivery of services to all students regardless of their socioeconomic background. However, despite this district's intention of addressing potential inequity in curriculum delivery, logistic regression revealed significantly lower odds of being selected for eighth-grade algebra for Black students. In addition, the distribution of students in eighth-grade algebra courses in the various schools in the district suggests a disparity of access to algebra in eighth grade according to the socioeconomic composition of each school. This was evidenced by the inverse proportion of students in eighth-grade algebra and students needing free and reduced lunch. This finding underscores the need for districts to be vigilant about administering more inclusive policies equitably across the total population.

Across the total population, the students who studied algebra in eighth grade ultimately took more mathematics courses in high school than those who waited until ninth grade to study algebra. This is an important finding that bears some examination and discussion. On the one hand, it is likely that students who took more mathematics courses simply had greater ability in math, greater natural interest in the subject, and greater satisfaction from taking math courses. On the other hand, a compelling question arises about the overlap group. Would the students in that group who did not study algebra in eighth grade have taken more mathematics courses if they had the opportunity to study eighth-grade algebra? Due to limits in data access related to student identification, subsequent math course-taking specifically among the overlap group was not analyzed. However, because they had the same entrance credentials, having studied eighth-grade algebra might have opened the door to the possibility of taking more math courses in high school. The types and number of math courses taken in high school also relate to the sequential nature of the mathematics curriculum and state requirements for mathematics courses. Eighth-grade algebra provides an early start for taking more advanced courses.

Taking more mathematics courses in high school can contribute to the overall mathematics literacy of the students involved. In a study of six schools in New York state, Spade, Columba, and Vanfossen (1997) found that "Course taking is the most powerful factor affecting students' achievement that is under the school's control" (p. 125). Schools can address inequities related to social class by examining course offerings and the procedures used to place students in classes. Gabelko and Sosniak (2002) found that engagement in serious academic pursuits took precedence over demographic identifiers like race, class, and ethnicity.

Another indicator of attainment is college attendance. In the entire sample, as well as in the overlap group, students in the eighth-grade algebra group attended college at a greater rate than students in the comparison group. Does greater access to eighth-grade algebra increase college attendance among a larger base of students? These results support that conclusion; however, this study was descriptive and nonexperimental. Therefore, it is impossible to draw causal inferences from the results of this study. A variety of other factors (i.e., motivation, parental pressure, and the like) might impact both enrollment in eighth-grade algebra and subsequent college attendance.

Finally, this study challenges traditional mathematics curricular patterns that have reserved eighth-grade algebra for selected students, because the selection processes may not be implemented equitably. Moreover, examination of the outcome measures among the overlap group suggests that selection processes can be flawed and can adversely affect the opportunities afforded to some students. The results further suggest that greater numbers of students can successfully complete eighth-grade algebra and accrue the benefits of that content. These results support the recommendations of other earlier studies (Gamoran & Hannigan, 2000; Ma, 2000; Smith, 1996) that report increased achievement patterns overall related to eighth-grade algebra.

Implications

Although this study supports greater access to the study of algebra in eighth grade, it does not support that study as the end-goal for all students in eighth grade. There will always be students on the lower end of the distribution who need more basic mathematics instruction in eighth grade. However, this study suggests that greater numbers of students may be capable of studying more rigorous mathematics topics in eighth grade. Students who complete Algebra I in eighth grade may reap long-term benefits, as evidenced by the higher percentages of students attending college. At the same time, a logical implication of the benefits of eighth-grade algebra for greater numbers of students is the question of appropriate differentiation for mathematically talented students. Assouline and Lupkowski-Shoplik (2005) cautioned against establishing curricula that improve instruction for all students but create ceiling effects for mathematically talented students. The inherent flaw in a standards-based curriculum that prescribes minimum mastery is that even when the bar for that minimum has been raised, there will be some students who can and will achieve mastery faster than others.

Recent efforts to increase the rigor of mathematics curriculum for all students have made progress toward both improving mathematics literacy and increasing the equity of course offerings across all student populations. This justifiable change in curriculum delivery for all students should not preclude opportunities for individual students who display mathematical talent and can benefit from both enrichment and acceleration. Future research should explore the implications of how offering algebra to greater numbers of students in eighth grade affects the options for those students who exhibit mathematical talent.

School leaders are often reluctant to provide acceleration for individual students because of the stigma attached to previous tracking policies that were rigid and exclusive (Colangelo, Assouline, & Gross, 2004). Appropriately challenging mathematics instruction should be provided for all students when they need it and not be restricted to longstanding traditional curriculum designs. Moreover, increasing the rigor of mathematics curriculum in the intermediate and middle school grades can lead to greater readiness for the study of algebra among more diverse student populations.

Conclusion

Standards-driven curriculum reform has challenged educators to provide rigorous experiences for the total population. This study suggests that eighth-grade algebra may be beneficial for greater numbers of students because it leads to increased mathematics literacy, as evidenced by the type and number of mathematics courses studied in high school. Eighth-grade algebra also led to greater college attendance, both in the percentage of students attending college and the type of college attended. This study suggests that increasing access to eighth-grade algebra may increase the incidence of advanced mathematics study among students not formerly involved in those courses.

References

Assouline, S., & Lupkowski-Shoplik, A. (2005). *Developing math talent: A guide for educating gifted and advanced learners in math*. Waco, TX: Prufrock Press.

Cogan, L., Schmidt, H., & Wiley, D. (2001). Who takes what math and in which track? Using TIMSS to characterize U.S. students' eighth-grade mathematics learning opportunities. *Educational Evaluation and Policy Analysis, 23,* 323–341.

Colangelo, N., Assouline, S. G., & Gross, M. U. M. (2004). *A nation deceived: How schools hold back America's brightest students* (Vol. 1). Iowa City, IA: The Connie Belin & Jacqueline N. Blank International Center for Gifted Education and Talent Development.

Gabelko, N., & Sosniak, L. (2002). "Someone just like me": When academic engagement trumps race, class, and gender. *Phi Delta Kappan, 83,* 400–408.

Gallagher, J. J. (2004). Public policy in gifted education. In S. Reis (Series Ed.), *Essential readings in gifted education, vol. 12*. Thousand Oaks, CA: Corwin Press.

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

Greene, B., Herman, M., & Haury D. (2000). *TIMSS: What have we learned about math and science teaching?* Columbus, OH: ERIC Clearinghouse. (ERIC Document Reproduction Service No. ED463948)

Hallinan, M. (2000, August). *Ability group effects on high school learning outcomes*. Paper presented at the Annual Meeting of the American Sociological Association, Washington, DC.

Ma, X. (2000, September/October). A longitudinal assessment of antecedent course work in mathematics and subsequent mathematical attainment. *Journal of Educational Research, 94*, 16–29.

National Center for Education Statistics. (1994). *Effective schools in mathematics* (NCES No. 065–000-0076-1). Washington, DC: Author.

National Center for Education Statistics. (1999). *Third International Mathematics and Science Study* (NCES No. 2001-027). Washington, DC: Office of Educational Research and Improvement.

National Center for Educational Statistics. (2001). *NAEP 2000 mathematics assessment*. Washington, DC: United States Department of Education, Office of Educational Research and Improvement.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Schiller, K. S., & Muller, C. (2003). Raising the bar and equity? Effects of state high school graduation requirements and accountability policies on students' mathematics course taking. *Educational Evaluation and Policy Analysis, 25*, 299–315.

Schmidt, W. (2003) Too little, too late: American high schools in an international context. In D. Ravitch (Ed.), *Brookings papers on education policy* (pp. 253–278). Baltimore: Brookings Institute Press.

Smith, J. (1996). Does an extra year make any difference? The impact of early access to algebra on long-term gains in mathematics achievement. *Educational Evaluation and Policy Analysis, 18*, 141–153.

Spade, J., Columba, L., & Vanfossen, B. (1997, April). Tracking in mathematics and science: Courses and course selection procedures. *Sociology of Education, 70*, 108–127.

Spielhagen, F. (2006). Closing the achievement gap in math: Considering eighth-grade algebra for all students. *American Secondary Education, 34*(3), 29–42.

VanTassel-Baska, J. (2000) Curriculum policy development for secondary gifted programs: A prescription for reform coherence. *NASSP Bulletin, 84*(615), 14–29.