Do Middle School Students Benefit from High School Math?

An Evaluation of High School Math Curricula on Middle School Student Achievement

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CONTENTS

EXECUTIVE SUMMARY

In the years since Oklahoma transitioned to new, more rigorous standards, the state has seen proficiency rates decline significantly in the eighth grade compared to previous grades. Given that just over 20 percent of eighth grade students are enrolled in either Algebra I or another high school math course, it has been posited that skipping eighth grade math to go directly into Algebra I may mean losing instruction on more basic arithmetic skills and thus performing more poorly on the state assessment.

A series of analyses were performed to ascertain what, if any, effect taking a high school math course such as Algebra I would have on performance of the eighth grade math assessment. Over 40,000 students were included in the analyses, which examined performance both on the overall score and each of the four main strands of the test: Numbers and Operations, Algebra and Algebraic Reasoning, Geometry and Measurement, and Data and Probability.

Results suggested that the effect of high school math is dependent on the prior math ability of the student. High ability students score better overall and in each of the four strands if they take high school math. Lower ability students, however, only see a benefit in performance on the first two strands, which are more closely related to basic arithmetic and algebra. The same students tended to perform more poorly on the latter two strands if they were enrolled in high school math. This pattern of results held up even after attempting to account for other factors that may affect whether a student enrolls in high school math (e.g., poverty). In fact, the boon for high ability students was persistent across all demographic groups. In other words, as long as the student was of high prior ability, high school math generally benefitted everybody.

Based on these analyses, the following four recommendations are suggested with respect to policies involving eighth grade students taking Algebra I:

1. Limit Algebra I to eighth grade students who have demonstrated high ability (e.g., consistently scoring proficient or above on prior math assessments). Students who have not already demonstrated mastery of grade-level concepts should take the middle school math curriculum.

2. Implement interventions in math in the early grades to increase the math ability of disadvantaged students so they are able to take advantage of high school math opportunities.

3. Rural districts that cannot support their own middle school Algebra I teacher may be able to take advantage of the internet to offer online Algebra I courses, either from a third party or using the Oklahoma virtual school model.

4. The state should conduct a follow-up study using ACT/SAT results from spring 2020 to determine whether the boost or decline in math performance persists beyond the end of the course.

INTRODUCTION

In the 2016–17 school year, Oklahoma implemented new, more rigorous mathematics standards to increase the college and career readiness of students. In both that and the following year, Oklahoma saw a decline in the percentage of students scoring proficient or higher in eighth grade relative to grades 3-7 (23 percent versus 38 percent proficient or higher in 2017; 20 percent versus 34 percent in 2018).

In Oklahoma, just over one out of five students takes high school math such as Algebra I instead of eighth grade math. Research in other states suggests that middle school students taking higher level math in eighth grade receive little to no boost in standardized test scores (Heppen et al., 2012; McEachin, Domina, & Penner, 2017), and in some cases may actually perform worse (Clotfelter, Ladd, & Vigdor, 2013). One theory for the lack of a positive effect is that skipping eighth grade math results in decreased instruction of basic arithmetic skills needed to perform well on the exam (Loveless, 2008).

The following analyses examined whether any significant effect existed between taking high school math and the performance of the eighth grade students on the Oklahoma School Testing Program (OSTP) math exam. Specifically, I examined whether high school math had any impact on both the overall score and each of the four strands assessed by the exam. The strands were looked at individually because even if math curricula has an effect on the overall score, the strength and direction of the effect may be different for the more basic strands compared to advanced strands that are more aligned to a high school math curriculum. In addition, given the national attention to the underrepresentation of women in STEM (Science, Technology, Engineering, and Mathematics; Pollack, 2013; Del Giudice, 2015), analyses were also broken down by gender.

METHODOLOGY

Student Population

The analysis included eighth grade students who received a score for the OSTP mathematics assessment in spring 2018. These students were placed in two groups based on their math coursework reported via Oklahoma's statewide longitudinal data system (the Wave). Students taking any math course for high school credit (e.g., Algebra I) were categorized as participating in high school math. Likewise, students who only took middle school math were grouped together. This resulted in a total sample of 43,712 students.

Middle school students are typically assigned to high school math based on their prior ability (e.g., previous assessment scores). Thus, any difference in score between groups could be due to the curriculum, or it could be due to the students' natural ability, or a number of other factors. I attempted to account for this by including student performance on the 2017 seventh grade math assessment as a measure of prior ability. This requirement reduced the number of students included in the analysis to 41,589. The number of students in each group at each level of the seventh grade test can be seen in Table 1.

Table 1

Students Enrolled in High School Versus Middle School Math by Prior Ability

	Middle School Math	High School Math
Below Basic	14,156	449
Basic	11,397	1,716
Proficient	6,239	4,876
Advanced	570	2,186

Prior ability is based on the performance level scored on the 7th grade test.

Assessment

The eighth grade OSTP math assessment consists of 50 items aligning with the Oklahoma Academic Standards (OAS) for Pre-Algebra. The assessment is scored on a scale between 200 and 400, which is further broken down into four performance bands: Below Basic, Basic, Proficient, and Advanced. Items are grouped by content into four strands.

The first strand, Numbers and Operations, relates to using real numbers to solve problems in various contexts.

The second strand, Algebraic Reasoning and Algebra, involves solving and interpreting linear functions and evaluating and solving algebraic expressions.

The third strand, Geometry and Measurement, covers the Pythagorean Theorem, surface area, and volume.

The fourth and final strand, Data and Probability, covers interpreting data and drawing conclusions from data as well as calculating experimental probabilities.

Table 2 contains the number of items within each strand and the percentage to which it contributes to the overall score. Table 3 displays the scale score cut points for each performance level (Basic, Proficient, and Advanced).

Table 2
Number of Items and Percent Contribution to the Overall Score for Each Strand

	Number of Items	Percent Weight
Numbers and Operations	9	18%
Algebraic Reasoning and Algebra	23	46%
Geometry and Measurement	10	20%
Data and Probability	8	16%

Table 3
Minimum Scale Score by Performance Level

	Scale Score
Below Basic	N/A
Basic	277
Proficient	300
Advanced	316

More information about the OAS can be found at https://sde.ok.gov/oklahoma-academic-standards.

Additional information about the assessment can be found at https://sde.ok.gov/assessment-material.

RESULTS

The average scale scores for students scoring at various levels of prior ability are displayed in Figure 1. For both genders and across the ability spectrum, students who took high school math outperformed students who did not. However, males who were proficient or higher on the previous exam received a slightly larger boost than females at the same level of prior ability. Additionally, the positive increase in the overall scale score grew larger as prior ability increased. For example, male students who were just Basic in seventh grade scored on average 5.1 points higher if they were enrolled in high school math (4.0 points for females). Male students who were just Advanced, on the other hand, scored 14.5 points higher if they were enrolled in high school math (11.5 points for females).

This pattern was less consistent even when looking at the individual strands. Figure 2 shows the average percentage correct within the Numbers and Operations strand. Students taking high school math got more items correct than students taking middle school math, with males generally receiving a larger boost than females (6.4 percentage points versus 4.9 percentage points). There was no differential effect of prior ability.

Figures 3 and 4 show the average percentage correct on the Algebraic Reasoning and Algebra strand and the Geometry and Measurement strand, respectively. Performance on Algebraic Reasoning and Algebra increased for all students taking high school math, and this increase grew as prior ability increased. There was no differential effect across genders. For the Geometry and Measurement strand, students at lower levels of prior ability performed no differently regardless of whether they were enrolled in high school or middle school math. Students of higher ability performed better if they took high school math. Again, the performance increase grew larger as prior ability went up, with males receiving a larger boost than females.

Finally, Figure 5 shows the average percentage correct on the Data and Probability strand. Within this strand, students of lower prior ability (e.g., Just Basic) actually performed worse if they were enrolled in high school math. Students of higher ability (Proficient and above) saw an increase to typical performance. This was also the only strand in which males performed better than females overall.

Figure 1. Average eighth grade math scale score for students grouped by gender, high school curricula, and previous performance on the seventh grade math assessment.

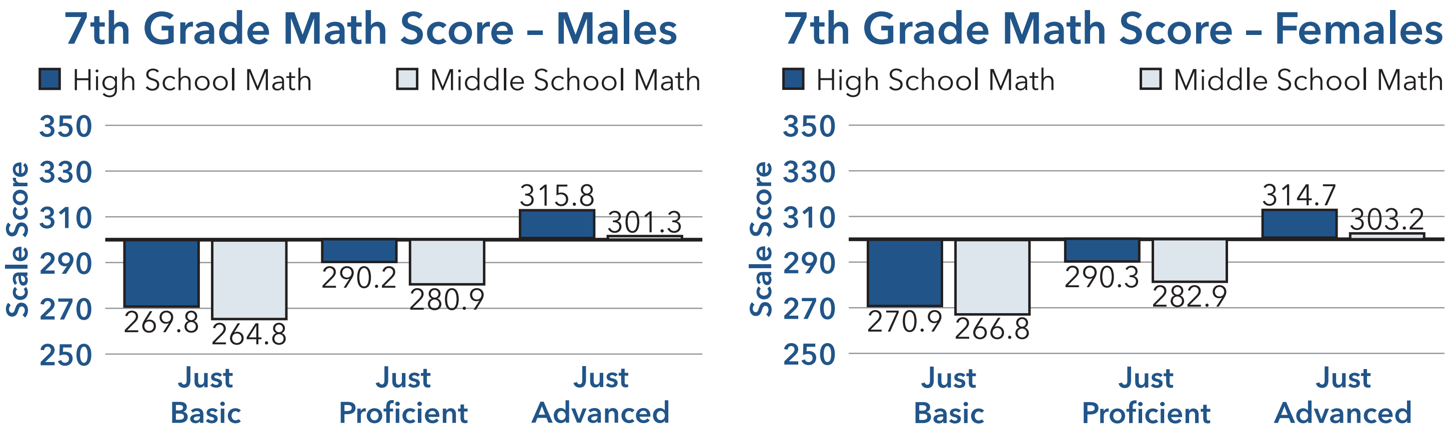


Figure 2. Average percentage correct on the Numbers and Operations strand grouped by gender, high school curricula, and previous performance on the seventh grade math assessment.

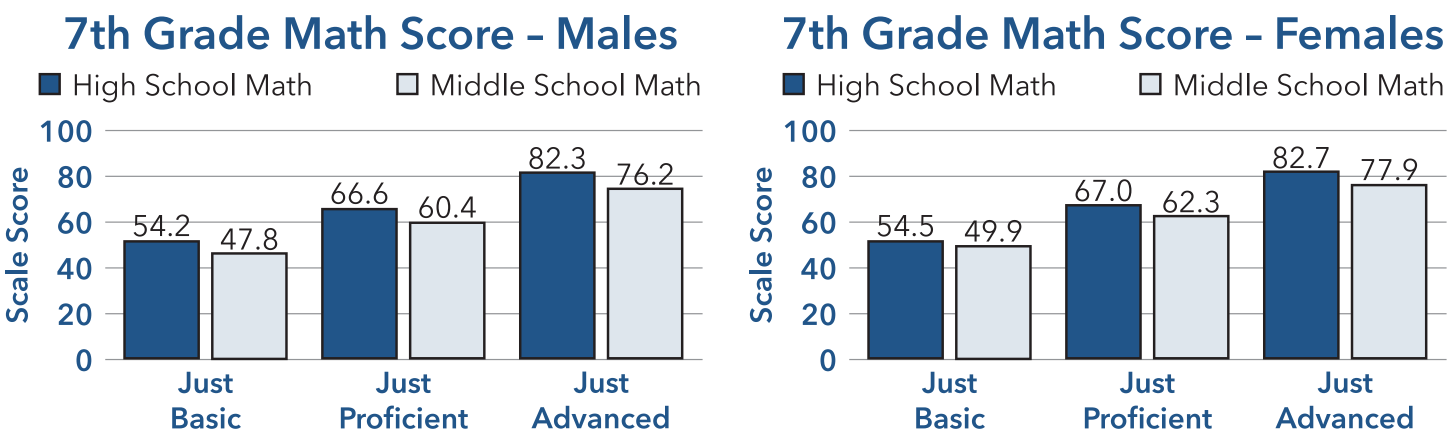


Figure 3. Average percentage correct on the Algebraic Reasoning and Algebra strand grouped by gender, high school curricula, and previous performance on the seventh grade math assessment.

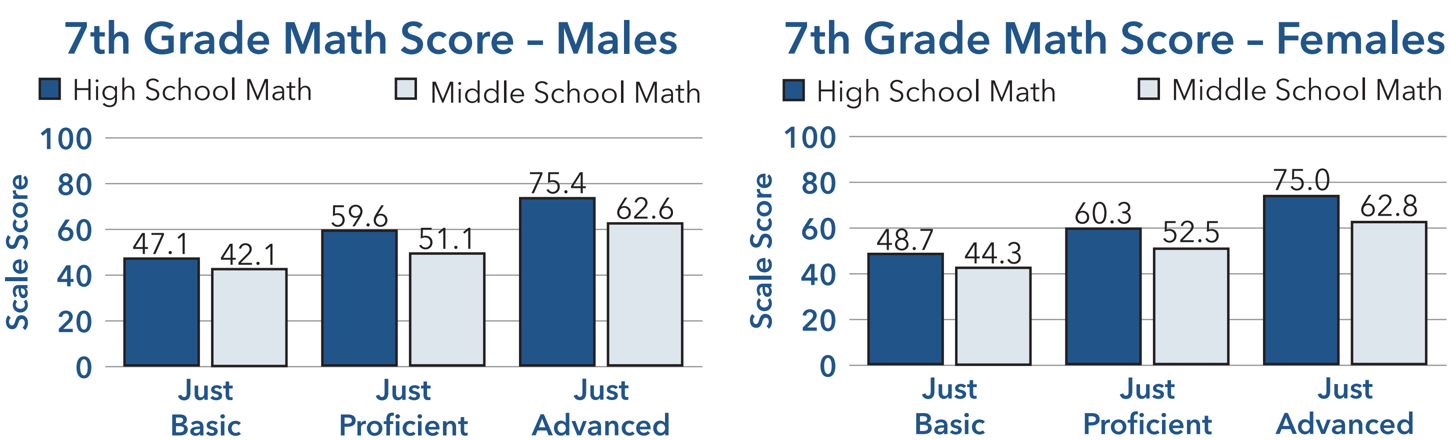


Figure 4. Average percentage correct on the Geometry and Measurement strand grouped by gender, high school curricula, and previous performance on the seventh grade math assessment.

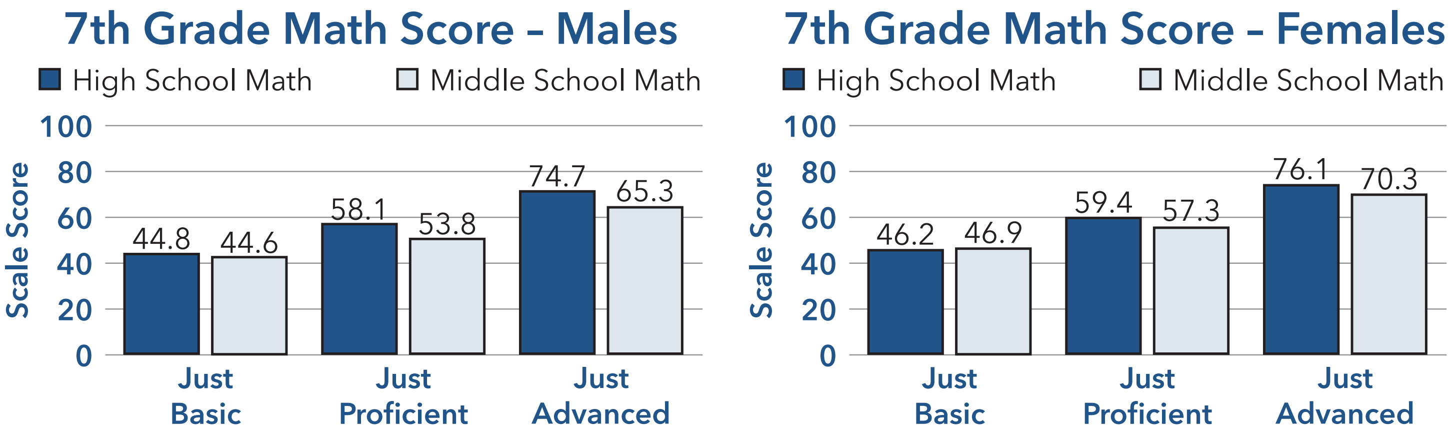
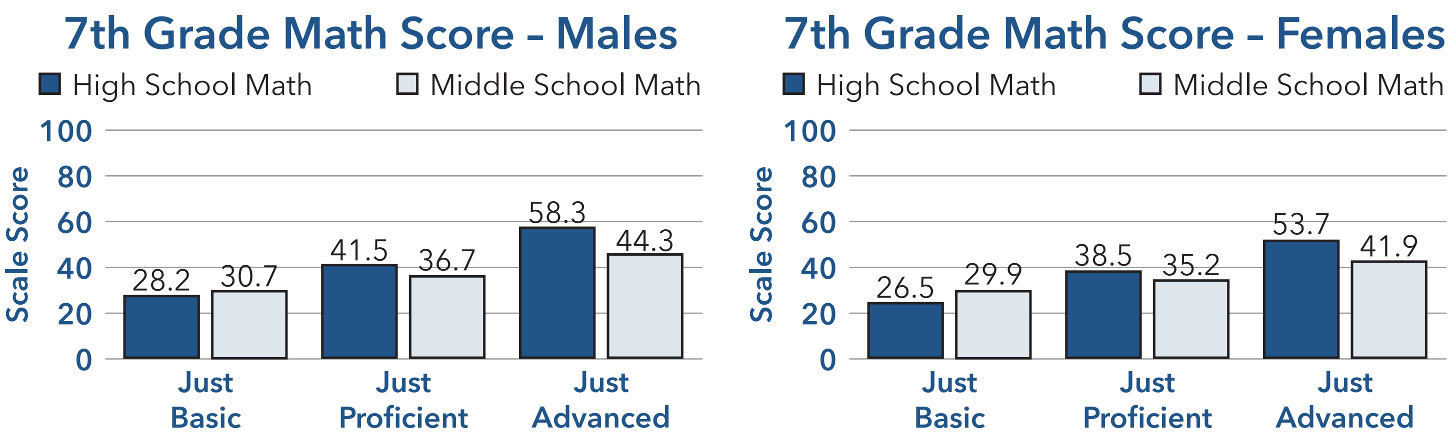


Figure 5. Average percentage correct on the Data and Probability strand grouped by gender, high school curricula, and previous performance on the seventh grade math assessment.



Gender Differences

As alluded to throughout the previous section, gender differences existed in both the overall score and each of the individual strands. Females generally outperformed males with the exception of the Data and Probability strand. This was especially true for students taking middle school math. Thus, the better performance experienced by males had the net effect of closing the gap between males and females rather than leading to males performing better than females.

ADDITIONAL ANALYSES

Covariate Analysis

Students are not randomly selected to take high school math. Rather, taking high school math is a function of availability, prior ability, and potentially other factors. Indeed, in the current sample, the following demographics were significantly predictive of whether or not a student was enrolled in high school math independently of prior ability and gender: disability status, gifted and talented status, homeless status, enrollment in an alternative education program, section 504 status, economically disadvantaged status, and race/ethnicity.

Of particular note, even with all else being equal, students with disabilities were 65 percent less likely to enroll in high school math than students without disabilities. Additionally, economically disadvantaged students were 40 percent less likely to take high school math than their non-economically disadvantaged peers.

On the other hand, with everything else being equal (e.g., similar prior ability, similar poverty status, etc.), African-American students were 43 percent more likely to enroll in high school math than their White peers. In addition, Hispanic/Latino students were also 78 percent more likely to enroll.

Thus, the previous analyses were repeated while statistically controlling for these demographics. If the same patterns emerge, it would provide additional evidence that the differences in performance are due to the differences in math curricula and not some unrelated demographic. Although the sizes of the effect were generally smaller, the increased performance for students taking high school math was still significant for the overall score, Numbers and Operations, and Algebraic Reasoning and Algebra. For Geometry and Measurement, students with higher ability still saw an increase in performance if enrolled in high school math.

However, students with lower ability who took high school math performed worse on this strand. Likewise, the pattern remained unchanged for the Data and Probability strand (lower ability students performed worse; higher ability students performed better).

Although all of the aforementioned effects were statistically significant, the magnitude of the effects were variable. The smallest effects were seen among lower performing students in their overall score (less than 0.1 standard deviations), whereas the largest effects were seen among higher performing students in the Algebraic Reasoning and Algebra strand (approximately 0.55 standard deviations), the latter of which is on par with the effect size seen by peer tutoring programs and greater than that of effective principals or school leaders (Killian, 2017).

Mixed Model Using Three Years of Previous Scores

Estimates of prior ability based on only one test score, while informative, are still subject to the volatility associated with a taking a single test on one day. Therefore, an additional set of analyses used the previous three years of student test scores (fifth, sixth, and seventh grade).

The scores were combined into a single factor to represent overall math ability and run through the same analyses described in the first subsection. Additionally, because both the availability and the class selection criteria vary across districts and may influence the results, the percentage of students enrolled in high school math within each district was also statistically accounted for.

This more technical analysis again revealed results very similar to the initial analysis. For students with high ability, performance on the eighth grade math assessment improved if they took high school math. Low ability students saw a small increase to their overall scale score driven by increased performance on the Numbers and Operations and the Algebraic Reasoning and Algebra strands.

In fact, contrary to previous analyses, the boost to Numbers and Operations performance was larger for low ability than for high ability students, likely because high ability students had already mastered this strand.

For the Geometry and Measurement and the Data and Probability strands, however, low ability students taking high school math performed worse than low ability students taking the regular eighth grade math curriculum.

CONCLUSIONS

The analyses described above demonstrate that taking high school level math in middle school (e.g., eighth grade students taking Algebra I) is only clearly beneficial for students of high prior ability. Students with lower ability perform only slightly better or even worse depending on the section of the assessment. This is consistent with studies showing that only the higher achieving students are likely to achieve a performance benefit from beginning high school math early (Clotfelder et al., 2013).

In the current sample, surprisingly, even lower ability students still saw benefits to their overall score and the first two strands (Numbers and Operations; Algebraic Reasoning and Algebra). In the third (Geometry and Measurement) and fourth (Data and Probability) strands, however, only high ability students saw a benefit. This contradicts the hypothesis that Oklahoma's decline in proficiency rates is due to a dearth in basic arithmetic skills. If anything, the data suggest that basic arithmetic skills are improved by taking high school math, and it is the higher level math skills that suffer if the student is not sufficiently advanced.

Two key differences exist between Oklahoma and states involved in studies that did not yield an effect. These differences could help explain the inconsistency in results.

First, in a North Carolina study, the outcome assessment used was an end-of-course Algebra I test (Clotfelder et al., 2013). Given that Algebra I is typically considered a high school class, it is likely more rigorous than the corresponding eighth grade math test.

Second, grade and course level standards vary across states. Both California (which was the state of focus in McEachin et al., 2017) and North Carolina are Common Core states, whereas Oklahoma is not.

Thus, the differences in results could potentially be because of the states' academic standards themselves.

There were persistent gender effects across most of the outcome measures. In general, females outperformed males in both the overall score and each of the individual strands except for Data and Probability. However, this gap was much more pronounced for students taking middle school math than it was for students taking high school math.

The interplay between high school math and prior ability persisted across multiple analyses, holding demographics constant and taking into account multiple years of testing. Most notably, even though demographics were related to performance on the assessment independent of prior ability, high ability students in all demographic groups saw increased performance after taking high school math.

Although it may seem intuitive that taking high school math would boost math performance for eighth graders, a growing body of research suggests that it may not help for all students, even if it does increase the likelihood that students will enroll in higher level math courses down the road (e.g., Clotfelter et al., 2013). The results of the current study suggests that there is truth to both sides of the equation.

All students in general do better on the portions of the test that measure basic arithmetic operations and algebra. However, only accelerated students show increased performance on the portions of the test associated with higher level math (e.g., geometry and statistics). Students coming into the eighth grade below grade level actually perform worse on these parts of the test if they take a high school math curriculum such as Algebra I.

Thus, although high school math may help these students 'catch up' on basic arithmetic, it may also set them up to have a lower probability of success in math courses beyond Algebra I.

Recommendations

Given the evidence produced by this study, it is apparent that neither Algebra I for all eighth graders nor eighth grade math for everyone would be an appropriate policy for students in Oklahoma. Rather, selection into Algebra I should be primarily based on an assessment of a student's math ability.

If a student is consistently scoring Proficient or Advanced on the state math assessments (or displaying similar performance on other measures), then that student is likely a good candidate for Algebra I. If a student has consistently scored Below Basic or Basic, then this student would likely be better served taking eighth grade math with perhaps targeted tutoring focusing on the more basic arithmetic skills. Of course, test results should never be the sole factor in determining placement. Instead, they should be considered in tandem with the student's previous portfolio of work and individual academic plan.

Even though students of color are actually more likely than their White peers to enroll in high school math, minority status is still strongly correlated with poverty. As students in poverty are also less likely to perform well on the assessments that are explicitly stated to be a measure of ability, such as state assessments (Croizet & Dutrévis, 2004; Farooq, Chuadhry, Shafiq, & Berhanu, 2011), there are fewer minority students in the current data set who show high enough ability to be able to take advantage of high school math.

Thus, districts should implement policies geared toward improving math ability for these students groups, preferably at an early age. Much like interventions to support reading proficiency in the third grade, interventions in mathematics in earlier grades may ultimately lead to more disadvantaged students being ready to take Algebra I in eighth grade.

Students of high ability are able to take high school math in eighth grade only if their district offers it. There are many rural districts in Oklahoma that do not have either the staff or student population to support high school math in the eighth grade.

Indeed, in the 516 districts represented in this study, 243 (47 percent) did not have a single eighth grade student enrolled in any high school math class. Taking advantage of online course programs in Algebra would increase access to Algebra I for high ability students in rural districts (Heppen et. al, 2012). Alternatively, the virtual school model could be used to allow students from different districts to enroll in the same course taught by a certified Oklahoma teacher.

Finally, this paper only examined the effects of high school math on the eighth grade assessment. A more relevant assessment on whether a student is college or career ready is the ACT/SAT assessment required by all 11th graders as part of Oklahoma's assessment and accountability program. Once the first eighth grade cohort under the new Oklahoma Academic Standards completes their junior year (May of 2020), a follow-up study is recommended to assess whether any benefits to performance persist beyond the end of the eighth grade school year.

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