Do 2nd Grade Math Scores Determine Students’ Futures?
A Statewide Student-Level Analysis of College Readiness and the Income-Achievement Gap

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This study explores the relationship between large, early income-achievement gaps and subsequent low rates of college readiness in mathematics among low-income high school students. Within-school course taking patterns in math are examined for the same students from 3rd through 12th grade, conditional on previous grade math scores and socioeconomic status, using detailed, statewide longitudinal data. The study asks the following at each grade level: i) are advanced classes identifiable within schools; ii) conditional on previous scores, do students in these classes advance faster; and iii) conditional on previous scores, are these classes more likely to be assigned to one group than another? Together, the findings indicate that, in terms of college readiness opportunities, it is better to be a low-performing high-income student than a high-performing low-income student, at every grade level, and that the share of students in each of these categories is quite large in most schools.


This study follows the entire statewide class of 1997-98 first-time 3rd grade students until either dropping out or graduating. Of the students who stayed in-state, 19.3% (or 13,185) dropped out. A series of logits are used to predict probabilities of dropping out of high school on determinants such as math and reading test scores, absenteeism, suspension, and retention, at each of the following grade levels: 3rd, 5th, 8th, and 9th. The same cohort and variables are then used to estimate benefits to the 15,737 students admitted to a special program ostensibly for academically and intellectually gifted children. I estimate the probability of admission for schoolmates with similar ability in math and reading to be substantially higher for those from upper income households. Finally, I conclude that extending similar resources to an equal number of high-risk students, as determined by their 3rd grade predicted probabilities, would lead to a 25% reduction in the total cohort dropout rate, and that even dividing existing resources between the two groups could cut dropout rates by half that.

Both studies were conducted at Duke University and can be accessed at SSRN: [http://ssrn.com/author=1589079](http://ssrn.com/author=1589079)
The Main Findings

• **Large subgroup outcome gaps exist for students with very similar test scores.** Large outcome gaps in high school graduation rates and college readiness are highly correlated with prerequisite opportunity gaps, and both are largely explained by socioeconomic status (SES), even controlling for measured ability.

• **Important within-school advanced opportunities begin in the earliest grades.** The findings contradict the common assumption that opportunities to prepare for advanced high school courses differ only by school or ability level and that students of similar demonstrated ability in the same schools are in equivalent classes and have the same access to advanced material and academic supports.

• **Income-achievement gap policies could improve by testing more assumptions.** The initial findings of these two studies were overly simplistic and inaccurate. The final conclusions benefitted from practitioner feedback on initial presentations that led to more empirical tests of the assumptions embedded in the initial models. These tests entailed collecting, linking, prepping, and documenting many more data points, for a total of 12 million student-year observations and dozens of new variables beyond test scores, as well as researching materials on the local education context and data collection process of both this study and those reviewed in the papers’ literature sections.
Classifications of the Cohorts and Courses

• **State Data Context:** The studies use statewide longitudinal student-level assessment and administrative data files from 3rd-12th grade and from 1998-2008, linked to teacher and course records. Socioeconomic categories of ‘low, mid, and high’ are derived as a composite step function of parents’ education and free/reduced lunch eligibility, and represent roughly one third of the student population each. The 1998 3rd-12th grade cohort follows all students who stayed in the state public school system (including those retained, transferring, or missing interim years of data). The 2004 8th-12th grade cohort are on-track graduates, and the 2006 5th-7th are all those in middle school non-remedial math.

• **Course Definitions:** The state university system defines college prep (or advanced) math as any class for which Algebra II and/or Geometry were a prerequisite (e.g., pre-calculus). The middle school advanced math classes (vs. standard) are defined by school or district website materials for parents (i.e., planning guides). The elementary school advanced math program is the locally-defined statewide Academically and/or Intellectually Gifted (AIG) program of differentiated curriculum, similar to the differentiated curriculum classes and programs in other states. Also, 3rd grade cohort findings match the subset with 2nd grade scores.
However, over one third of each SES subgroup scored in the average 3rd grade math proficiency level (i.e., ACH Level III). These subgroup mean scores were almost identical, but the gaps in student outcomes by SES remain large. This research explores potential causes.
Many income-achievement gap studies reviewed in these two papers attribute large differences in high school outcomes to large school-entry gaps found in mean scores in the earliest tested grades (at the end of 3\textsuperscript{rd}). But, high and low SES students’ scores are the same within 2\textsuperscript{nd} grade achievement categories (measured by 3\textsuperscript{rd} grade pretests), diverging prior to 3\textsuperscript{rd} grade post-tests.
The Gaps Are Only Partly Explained by Subgroups Attending Very Different Schools

The graph shows each elementary school’s SES composition of 1998 3rd graders, as a vertical line. The schools on the far left serve primarily upper-income households, while those on the far right serve high-poverty concentration areas. However, the majority of schools can be seen to have a mix of the three SES subgroups that is roughly similar to the overall state mix. Studies reviewed in these papers show similar distributions for other states. Additionally, several of those studies show that random assignment to upper-income neighborhood schools of families qualifying for low-income housing resulted in no educational gains.
These histograms show the statewide distribution of 2nd grade math test scores for all high SES students (in the top panel) and low SES students (in the bottom panel). While there is seen to be significant overlap in the scores of many students from both SES subgroups, the transparent bars show the different share of each subgroup subsequently assigned to the gifted program. (Students in the housing studies described in the last slide were also not admitted into the higher tiers of their school system’s differentiated curriculum in math or reading.)
Placement into the AIG math and/or reading programs, available in every school, was very similar. Roughly 90% of students placed into the program in one subject were also placed in the other. The graph shows the predicted probabilities of 3rd grade students being placed into AIG as a function of their combined 3rd grade math and reading scores, for each SES subgroup, and controlling for their school and other characteristics. Mid and low SES students scoring one standard deviation (SD) above average had a roughly 20% probability of enrollment, while similarly-scoring high-SES students had more than a 50% likelihood.
These are the predicted reductions in the probabilities of dropping out of high school following various extensions of the high-growth characteristics of gifted enrichment programs to at-risk students. (They correspond to the graphs in the next slide.) As several studies reviewed in the papers have shown, AIG-type enriched curriculum benefits lower-achieving students as well.
Predicted probabilities of dropping out of high school fall significantly, from the highest levels (the solid line), for initially low scoring students. For example, the probability for a 3rd grade student who scored a full standard deviation below average for the state (-1SD), falls from over 30% to approximately 20% when the total impacts of higher growth (on absenteeism, suspensions, and retention) are included. Though, there is little change in the already low probability for high scoring 3rd grade students.
Similar to AIG programs, special education services for Specific Learning Disability (SLD) lead to higher growth in reading scores, controlling for initial ability. Placement is also similar to that of the AIG programs, in that high-SES students qualify for these services at much higher initial reading levels. The top panel is high-SES students, the bottom is low-SES. The left side are all non-SLD students, and the right is SLD. Red 8th grade reading is compared to blue 3rd.
Teacher Value-Added Measure (VAM) Studies Misattribute These Assignments

The commonly cited 0.10 - 0.20 SDs of student growth that studies attribute to a one SD span in teacher VAMs, can actually be explained by classroom assignments.

Mean classroom student test score growth above or below what is predicted by previous scores and other characteristics, such as race, gender, FRL, and school- and class-level means (‘simple estimates’) are attributed to the classroom teacher’s effectiveness (or VAM). These classroom or teacher effects are plotted here over the ratio of AIG peers in each class. This large gap is then commonly attributed to some unknowable difference in ability. The complex model includes previous scores, FRL, SES, AIG, SLD, etc., at every level, thus identifying the gap through school, classroom, and program assignments for both the students and their teachers.
Outcome Gaps Are Not Explained by Teacher Effectiveness as Measured by VAMs

The set of Chetty et al., papers critiqued in this research is the most commonly cited ‘evidence’ that VAMs capture a teacher’s effectiveness and lead to policies that will close equity gaps. The left-hand bars show the percent of 19 year olds attending college for the 80th and 20th income percentiles. Using the same tax data, the right side shows the sample means for: college attendance, persistence, employment, teen birth, percent of college grads in young adult zip code, and 401(k) savings accounts. Also shown, is the impact of a full SD increase in teacher VAM for each, as reported in Tables 2-4 of Chetty et al, 2013. At less than a percentage point each, it appears VAMs are not very useful for explaining the important role teachers play.
Outcome Effects from Early Differential Placements for Students of Similar Ability

5th Grade

High Scores

Advanced Math

6th Grade

6th Grade Advanced Math

7th Grade Pre-Algebra

8th Grade Algebra I

State Univ. Prerequisite Math Courses

6th Grade Standard Math

7th Grade Standard Math

8th Grade Standard Math

Less than College Prerequisite Math

Difficult to Enter Advanced Track from Standard

Instead, as with early grade programs, class assignments continue to play an important role.
These histograms show the statewide distribution of 5th grade math test scores for students placed into 6th grade advanced math (in the top panel) and standard math (in the bottom panel). There is similar overlap in the scores, and regressions show that even within-schools, placement varied systematically after controlling for scores.
### Differential Middle Grade Math Placement Probabilities and Outcomes

#### Table 2: 6th Grade Advanced Math Probabilities and Outcomes Controlling for 5th Grade Ability

<table>
<thead>
<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
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</thead>
<tbody>
<tr>
<td>Probability of Advanced 6th Grade Math</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th Grade AIG Status</td>
<td>0.465* (0.018)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents’ Education = College or Higher</td>
<td></td>
<td>0.087* (0.005)</td>
<td></td>
</tr>
<tr>
<td>Free or Reduced School Lunch Eligible</td>
<td></td>
<td></td>
<td>-0.061* (0.005)</td>
</tr>
<tr>
<td>5th Grade EOG Math z-score</td>
<td>0.009* (0.001)</td>
<td>0.017* (0.001)</td>
<td>0.017* (0.001)</td>
</tr>
<tr>
<td>5th Grade EOG Reading z-score</td>
<td>0.008* (0.0004)</td>
<td>0.013* (0.001)</td>
<td>0.014* (0.001)</td>
</tr>
</tbody>
</table>

#### 6th Grade vs. 7th Grade Advanced Math on 6th and 7th Grade Outcomes

<table>
<thead>
<tr>
<th></th>
<th>6th Grade</th>
<th>7th Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>EOG Math Scale Score (1.9pts equals 0.20 z-score SDs)</td>
<td>1.889* (0.095)</td>
<td>1.905* (0.086)</td>
</tr>
<tr>
<td>Unexcused Absences (6th grade mean is 3.4; 7th grade is 3.9)</td>
<td>-0.304* (0.047)</td>
<td>-0.389* (0.053)</td>
</tr>
<tr>
<td>Days Suspended (mean for each grade is 0.9 days)</td>
<td>-0.112* (0.039)</td>
<td>-0.137* (0.037)</td>
</tr>
</tbody>
</table>

The regression results show that after controlling for 5th grade math and reading scores and other characteristics (e.g., absenteeism), high-SES and/or AIG schoolmates were much more likely to be assigned to 6th grade advanced math and to have much better 6th grade outcomes.
Policies mandating Algebra I by 8th grade for all students were explored by some states and districts as a way to close college readiness gaps. But as the previous slides show, preparation for Algebra I is extremely important. This graph also shows that while early Algebra is correlated with advanced math, other students have enough years to take advanced math, but few do so.
Taken Together, Predicted Probabilities of Advanced Opportunities by Scores and SES

<table>
<thead>
<tr>
<th></th>
<th>Coll/NoFRL (high SES)</th>
<th>Other (mid SES)</th>
<th>NoColl/FRL (low SES)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advanced Math on 3rd Grade Scores:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pr(AdvMath) at Each Student’s Observed Values</td>
<td>77.25</td>
<td>56.03</td>
<td>37.41</td>
</tr>
<tr>
<td>At Low SES 3rd Grade Math Mean</td>
<td><strong>65.17</strong></td>
<td>52.11</td>
<td>37.41</td>
</tr>
<tr>
<td>At High SES 3rd Grade Math Mean</td>
<td>77.25</td>
<td>64.19</td>
<td><strong>49.49</strong></td>
</tr>
<tr>
<td><strong>Advanced Math on 7th Grade Scores:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pr(AdvMath) at Each Student’s Observed Values</td>
<td>78.64</td>
<td>55.51</td>
<td>38.00</td>
</tr>
<tr>
<td>At Low SES 7th Grade Math Mean</td>
<td><strong>62.31</strong></td>
<td>50.75</td>
<td>38.00</td>
</tr>
<tr>
<td>At High SES 7th Grade Math Mean</td>
<td>78.64</td>
<td>67.08</td>
<td><strong>54.33</strong></td>
</tr>
<tr>
<td><strong>Algebra 8th on 3rd Grade Scores:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pr(Alg8th) at Each Student’s Observed Values</td>
<td>41.01</td>
<td>21.90</td>
<td>9.83</td>
</tr>
<tr>
<td>At Low SES 3rd Grade Math Mean</td>
<td><strong>28.62</strong></td>
<td>17.89</td>
<td>9.83</td>
</tr>
<tr>
<td>At High SES 3rd Grade Math Mean</td>
<td>41.01</td>
<td>30.29</td>
<td><strong>22.21</strong></td>
</tr>
</tbody>
</table>

Different grade-level advanced opportunities conditioned on opposite SES scores. At each grade, it is better to be a low-scoring high-income student, than a high-scoring low-income student.
The probability of enrollment in college prep math in high school is higher for students with higher initial 3rd grade math ability, controlling for school and other characteristics. But it is also almost twice as high for an average scoring high-SES student as an average scoring low-SES student. And a low- or mid-SES 3rd grader who scores a full SD above average in math, has the same college prep probability as a high-SES schoolmate who scores below average in math.
Conclusion: Policy and Practice Implications (Described in More Detail in the Papers)

• **Research of Related Factors:** The papers review dozens of studies of other important related challenges to low-income student success, including differences in resources available for early-childhood and supplementary education, as well as important school-level resource differences for many students, and other financial and social-capital contributors to college preparation, enrollment, and success.

• **Practitioners Implementing Changes to Policies:** The papers also describe the effects of policy changes initiated by practitioners to increase access to advanced math opportunities for previously underrepresented students. Independent of this research, middle school counselors, teachers, and principals reached out to a group called Edstar Analytics to help them use the state data system to identify students who were passed over for advanced math placements for which their scores qualified them. The evaluations of these policy shifts found that the newly-identified students achieved similar success in the initial and subsequent grades. They also found a significant reduction in total suspensions for the entire school and greater teacher satisfaction in the following years (Stiff, & Johnson, 2011;Stiff, Johnson, & Akos, 2011).
Questions/Discussion

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