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HIDDEN DISPARITIES: HOW COURSES AND CURRICULA SHAPE OPPORTUNITIES IN MATHEMATICS DURING HIGH SCHOOL¹

Kathryn S. Schiller*,

University of Albany, State University of New York

William H. Schmidt,

Michigan State University

Chandra Muller, and

University of Texas at Austin

Richard Houang

Michigan State University

Abstract

Efforts to promote academic achievement by increasing access to courses, especially in mathematics, may mask educational disparities if variations in curriculum are not also monitored. A multi-dimensional description of students' mathematics curricula during high school was obtained from analyses of surveys, transcripts, and textbooks collected for a nationally representative study of adolescents during the mid-1990s. Few gaps in the number of years or credits in mathematics coursework were found. However, the quantity and cognitive challenge of instructional materials in textbooks adopted for those courses differed significantly both across and within mathematics tracks. Differences in the quality of curriculum accumulating during high school were also related to parents' education level. Reducing such gaps in learning opportunities would require teachers to supplement adopted instructional materials to ensure that all students receive a high quality mathematics curriculum.

The assignment of students to classes for the delivery of instruction, most frequently based on their age and on topic being studied, is a key organizational feature of schools. These classes are where students, teachers, and curricular materials combine to create learning environments that vary in opportunities to engage educational activities (Barr & Dreeben, 1983; Kilgore & Pendleton, 1993) As students progress through their academic careers, they experience a series of classes and curricula that often result in increasingly divergent

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*Address correspondence to: Kathryn Schiller, University at Albany, State University of New York, Education 313, EAPS, Albany, NY 12222. schiller@albany.edu.

educational experiences (Alexander, Entwisle, & Horsey, 1997; Riegle-Crumb, 2006). For well over half a century, how to address possible sources of these persistently accumulating disparities has been a major focus of policy initiatives, with arguably little success in narrowing gaps in academic achievement.

In this article we use a recently released nationally representative longitudinal study (Schiller et al., 2007) that includes information from students' high school transcripts and schools' textbook adoptions to highlight two distinct dimensions of students' learning opportunities that can be generally described as *courses* and *curriculum* (Kilgore & Pendleton, 1993). Prerequisites for courses constrain students' progress (McFarland, 2006; Schneider, Swanson, & Riegle-Crumb, 1997) and academic tracking segregates students between courses (Frank et al., 2008; Hallinan, 1991; Lucas, 1999), both of which are major sources of disparities in high school learning opportunities. In addition, the quantity, cognitive challenge, and accessibility of instructional materials intended for or actually used in classes reflect differences in curriculum quality (Floden, 2002; Porter & Smithson, 2001; Schmidt, McKnight, & Raizen, 1997). Similarly titled courses often differ dramatically in their content within and between schools, with some offering watered-down versions of courses that are rich in challenging material in other schools (Gamoran, Porter, Smithson, & White, 1997). Thus, students whose transcripts are identical may have had very different learning opportunities during high school due to the curriculum in their courses.

Employing multi-dimensional measures of learning opportunities, we examine how ethnic minorities and low-socioeconomic groups are not only educationally disadvantaged in access to courses but also in the curriculum content of the courses in which they do enroll. One goal is to determine whether educational disparities are underestimated, if not totally masked, when examining course credit accumulation without taking into account indicators of curriculum quality. We are also concerned with determining whether students in more basic mathematics programs, who are most likely to need a higher quality curriculum, are often in a series of courses providing limited opportunities to engage in cognitively challenging tasks.

DIMENSIONS OF LEARNING OPPORTUNITIES

Since the early 1980s, educational reform efforts in the United States have often focused on raising academic standards and achievement for all students by increasing course-taking requirements in core academic subjects (Stevenson & Schiller, 1999). In mathematics, these efforts are reflected in a continuing rise in the number of credits, especially in advanced courses, being earned by high school graduates (Hoffer, 1997; Schiller & Muller, 2003). In addition, gaps in course-taking between socio-demographic groups closed significantly over this period (Rampey, Dion, & Donahue, 2009), suggesting that fewer children were being left behind.

Paradoxically, however, scores on the National Assessment of Education Progress (NAEP) were generally stagnant during this period and gaps in scores between socio-demographic groups remains statistically significant (Rampey et al., 2009). In addition, both in the late 20th and early 21st centuries, colleges and universities continually decried the need for remedial courses for large percentages of undergraduates, which raises questions about the quality of high school courses (Dougherty, Mellor, & Jian, 2006). These trends suggest that equalization of enrollment rates in courses traditionally considered "college preparatory" may be overlooking changes in course content as the curriculum becomes watered down to accommodate greater diversity in students' academic and socio-demographic background (McPartland & Schneider, 1996). To the extent that other schools resist this trend, differences in learning opportunities may be underestimated by failing to account for both

course-taking patterns and the quality of curriculum intended for those courses. In this article, we explore whether efforts to increase achievement in high schools by focusing on a common core curriculum for all students has produced a system that hides stratification of learning opportunities.

Course Enrollments as Opportunities to Learn

In these analyses we focus on mathematics as a core subject that is clearly hierarchically structured (McFarland, 2006; Riegle-Crumb, 2006), its mastery is more strongly influenced by school processes than other subjects (Suter, 2000), and students' success has consequences for post-secondary schooling (Schneider, 2001). The desired core set of courses in this subject is usually designated as Algebra 1, Geometry, and Algebra 2 (National Mathematics Advisory Panel, 2008). During the 1990s, over 84% of high school graduates had taken at least Algebra 1 and Geometry, with over 60% also taking at least Algebra 2 (Rampey et al., 2009). On the surface, the majority of graduates appear to have similar exposure to core high school mathematics.

The sequential nature of mathematics, however, means that the timing of when key prerequisite courses are taken has clear consequences for how far in the subject students can progress during high school. The normative sequence of mathematics courses in U.S. school systems is to start with Pre-algebra and progress through Algebra 1, Geometry, Algebra 2, Trigonometry or Pre-calculus, and to culminate in Calculus (Riegle-Crumb, 2006; Schiller & Hunt, in press).² This sequencing of courses reflects institutionalized pedagogical understandings of how mastery of less complex topics is required before students can progress to more advanced topics (National Council of Teachers of Mathematics, 2004; National Mathematics Advisory Panel, 2008). Students typically gain positional advantages from being placed in more advanced courses earlier in their careers (Kelly, 2009; Schneider et al., 1997; Smith, 1996). The sequencing of courses means that two students who take three years of mathematics courses could have very different learning opportunities. For example, a high school graduate who takes Pre-algebra, Algebra 1 and Geometry would be viewed very differently by college or university from one who takes Geometry, Algebra 2, and Pre-calculus. Because of such differences, course-based indicators of academic track usually consider when students take a particular mathematics course (Heck, Price, & Thomas, 2004; Lucas, 1999). In our analyses, we classify students into mathematics tracks by when, if at all, they took Algebra 1 because the earlier they take this gatekeeping course, the more likely they are on track for taking Pre-calculus or Calculus in high school.

Curriculum as Opportunities to Learn

In addition to institutionalized indicators of academic status, course placements also reflect differences in opportunities for learning a subject through the quantity and cognitively challenging nature of curriculum as well as likely differences in the quality of instruction. Courses and curriculum can be strongly associated. For example, advanced courses are often rich in cognitively challenging material while basic courses feature a curriculum so diluted that they are caricatures of regular courses (Gamoran et al., 1997; Oakes, 2005). Analyses of the Third International Mathematics and Science Study: 1995 (TIMSS:1995) found only a moderate consistency in U.S. middle schools between textbook content and course title, with only 70% of students enrolled in Algebra 1 using an algebra textbook (Cogan, Schmidt, & Wiley, 2001). Given the strong correlation between textbook content and teachers' reports

²Variation in the sequence of mathematics courses is usually due to differences in school policies (e.g., a small number of schools require students take a second-level algebra course before they take geometry) and individual deviations (e.g., accelerating through the mathematics sequence by doubling up on courses in a given year). Also, while some school systems have implemented integrated mathematics curriculum, the emphasis of topics in courses often follows the normative sequence.

of topic coverage (Schmidt et al., 1997; Tarr, Chavez, Reys, & Reys, 2006), these results suggest that many high school freshmen who had so-called “Algebra” in middle school may need to take Algebra 1 anyway as preparation for advanced topics in later courses (Riehl, Pallas, & Natriello, 1999). Thus, even courses with similar titles or catalogue descriptions often differ dramatically in their content.

In this article, we examine differences between courses throughout students’ high school careers on two key dimensions of curriculum that apply to all mathematics courses: the amount of instructional material most likely provided and how cognitively challenging that material was.³ This information was obtained from a fine-grained coding of textbooks, called “potentially implemented curriculum” by Valverde, Bianchi, Wolfe, Schmidt, and Houang (2002, p. 13), which sets probabilistic limits on topical coverage and cognitive demand in a course. While teachers frequently do not cover an entire textbook and occasionally use supplementary instructional material, textbooks are usually the *de facto* curriculum in classrooms (Barr & Dreeben, 1983; Tarr et al., 2006), especially in mathematics (Schmidt et al., 1997).

Courses criticized as watered-down are often described as lacking sufficient time for students to learn the desired topics and skills (McPartland & Schneider, 1996; Porter & Smithson, 2001). In lieu of teachers’ reports, textbooks provide reasonable indicators of the amount of time spent in classrooms on learning the intended curriculum (Cogan et al., 2001; Floden, 2002; Tornroos, 2005). Shorter textbooks presenting topics in isolated discrete units are likely to take less time to cover and provide less exposure to key concepts when compared to longer books integrating discussions about topics within and across chapters (Tarr et al., 2006). In this study, we make no claims about what is a “sufficient” quantity of instructional material but show that courses do differ dramatically from what is the norm in mathematics courses across the nation.

Even if not lacking in the quantity of material presented, watered-down courses are also often described as lacking sufficient cognitive demand for student learning (Gamoran et al., 1997; Oakes, 2005). Distinct from the topics covered, cognitive demand is used to describe the tasks students are asked to do when engaging with the instructional material or answering examination questions (Schmidt et al., 2001; Zhu & Fan, 2006).⁴ While the number of categories for classifying tasks into levels of difficulty varies across studies, the lowest level usually consists of routine tasks (e.g., using equipment, recalling terminology, and recognizing equivalents) that require relatively basic cognitive functions. In contrast, the highest level usually includes complex tasks (e.g., developing algorithms, revising proofs, and solving a novel problem) that require more sophisticated cognitive functions. Textbooks featuring mostly routine drill-and-practice exercises provide relatively limited opportunities for students to engage in authentic learning compared to those with cognitively challenging problems (Floden, 2002; Tarr et al., 2006; Valverde et al., 2002). Again, in this study we make no claims about what is “sufficient” cognitive challenge but show how courses differ dramatically in the level of challenge they most likely provide students.

Together, time spent and tasks attempted are both factors that contribute to students’ opportunities to learn a subject and, thus, are key components of a quality curriculum in advanced as well as basic courses (Gamoran et al., 1997). Shorter textbooks featuring routine tasks provide fewer opportunities to learn than longer ones with similar exercises. In

³Some evaluators describe additional characteristics of curriculum, such as *mode of presentation* (Porter & Smithson, 2001) and *accessibility* (Boaler & Staples, 2008), which are not appropriate for this study, as neither scale such that accumulation of differences across time are additive.

⁴Most authors also distinguish cognitive challenge from the form of a question, for example, multiple-choice or open-ended (Zhu & Fan, 2006).

contrast, a shorter textbook that encourages students to engage in more cognitively demanding tasks may provide more learning opportunities than a longer book emphasizing routine drill-and-practice. While we make no claims here about what combination of quantity and cognitive challenge of material best promotes learning, we do explore variations in curriculum quality throughout high school based on when students first enrolled in Algebra 1.

Research Questions

We address three main research questions using recently released education and curriculum components for a nationally representative study of American adolescents during the 1990s. First, to what extent did the quantity and level of challenge of instructional material in textbooks vary across and within mathematics tracks each year of students' high school careers? Second, by the end of high school, how did students' socio-demographic and academic backgrounds relate to accumulated differences in quality curriculum and traditional measures of learning opportunities during high school? Third, how did gaps in quality curriculum exposure between socio-demographic groups and mathematics tracks develop over the four years of high school? Together, these three sets of analyses reveal how both course enrollments and curriculum content contribute to perniciously developing educational disparities.

DATA AND METHODS

Sample

These analyses utilize information from high school transcripts and textbook adoption lists collected for Adolescent Health and Academic Achievement (AHAA) and linked to survey data from the National Longitudinal Study of Adolescent Health (Add Health). Add Health started in 1994-95 with a nationally representative longitudinal sample of 20,746 students in grades 7 through 12 in 80 high schools or an associated feeder school (Harris, Florey, Taboy, Bearman, Jones, & Udry, 2003). Wave III was conducted in 2001-2002, by which time the vast majority of Add Health participants had graduated from high school. In addition to surveys, high school transcripts were collected for 12,109 students (92% of the Wave III respondents) from approximately 1,300 high schools they last attended (Riegle-Crumb, Muller, Frank, & Schiller, 2005). The transcripts were coded using procedures identical to those for the U.S. Department of Education's national transcript studies.

The AHAA curriculum component provides detailed information concerning the content of textbooks that schools reported using in mathematics courses appearing on students' transcripts (Schiller et al., 2007). Approximately 110 high schools provided textbook adoption lists for their mathematics courses. Content information was drawn from a data base of over 145 mathematics textbooks coded for either the Longitudinal Study of American Youth (LSAY) or AHAA using the framework developed for TIMSS: 1995 (Valverde et al., 2002). The coding process and derived measures will be described in more detail later. In these analyses, we use a sub-sample of 3,523 students for whom curriculum indicators were available for the mathematics courses they took each year during high school. An attrition analysis indicated that students for whom transcript and textbook information are available were slightly more likely to be white, have more educated parents, live with both natural parents, and were in the top two mathematics tracks.⁵ We use

⁵While overall more educationally advantaged than the full Add Health, the subsample with transcript and textbook information contained sufficient numbers of ethnic and racial minorities, those with less educated parents, and in the lower mathematics tracks to reliably estimate statistical coefficients. The attrition analysis is available from the contact author.

sampling weights to adjust for differences in sampling probability and non-response to allow generalizations to high school students during the mid-1990s.

Socio-demographic Background Variables

We include standard socio-demographic and school context indicators as independent variables in these analyses. Information on students' *socio-demographic backgrounds* was obtained from the surveys and includes indicators of their gender, race/ethnicity, family structure, and parents' highest level of education.⁶ Our indicators of *school characteristics* were obtained from administrator questionnaires and included urbanicity, large school (over 1,000 students enrolled in grades 9–12), and number of mathematics course credits required to earn a regular diploma.⁷

Mathematics Course Enrollment Variables

Measures of students' mathematics *course enrollments* were obtained from their high school transcripts. In particular, we created a variable that indicated when, if at all, Algebra 1 appeared on a student's transcript. As noted earlier, by the mid-1990s the vast majority of high school students took Algebra 1 sometime before or during high school, but differed in when they completed this key course. Here we use an indicator for whether a student took Algebra 1 prior to entering high school (advanced track; 21% of the sample), their freshman year (regular track; 71% of the sample), as a sophomore (low regular track; 5% of the sample), or after 10th grade (basic track; 3% of the sample). Students who did not take Algebra 1 or higher courses at any point during high school are included in the "basic" category. In general, students usually enrolled in courses classified as pre-algebra or general mathematics prior to taking Algebra 1.⁸

We use three transcript-based measures of the *amount of mathematics* to which students were exposed over the course of high school. The most basic measures were simply the number of years in which they took at least one mathematics course (mean = 3.35; sd = 0.76) and the number of semesters of mathematics courses attempted (with two semesters given a value of 1 year; mean = 3.65; sd = 1.04). We also used the total number of Carnegie Units (in which 1 is the equivalent of meeting an hour per day for a school year; mean = 3.30; sd = 1.07) that a student earned while in high school.

Curriculum Content Variables

The measures of *curriculum content* reflect the quantity and cognitively challenging nature of instructional material in textbooks that schools adopted for the courses students took. Trained and supervised by the Center for Research in Mathematics and Science Education⁹ at Michigan State University (MSU), the coders had graduate-level education in mathematics or mathematics education. An abbreviated version of TIMSS:1995 procedures, the coding system was designed to be low-inference, in that coders only recorded which of approximately 160 topics and around 30 tasks were explicitly asked about in each chapter review question, from which detailed book-level summaries were created as described in Schiller et al. (2007).

Three course summary measures included in AHAA are used for this article. A fundamental indicator of curriculum content is a measure of the *quantity* of instructional material in the

⁶Detailed information on the source and coding of these and other variables can be obtained from the contact author.

⁷Included in preliminary models, average parents' education level in the school was dropped because it was not a statistically significant predictor for any outcome after controlling for individual students' parental education level.

⁸Courses classified as "special education" or "resource room" were not included in the indicators of mathematics course taking for AHAA and were not part of the curriculum component.

⁹Formerly the U.S. TIMSS National Research Center.

textbook that takes into account the length of the book and the integration of topical coverage within chapters.¹⁰ Assuming that the typical book is written for a year-long course, this measure was standardized to have a mean of 1 (to be considered equivalent to a year of instructional material) and a standard deviation of .25 (to be considered equivalent to half of a semester) to facilitate substantive interpretation of the scale.

Another fundamental measure of curriculum content is how cognitively *challenging* the instructional material is based on the types of tasks students are asked to perform (also referred to as performance expectations in Valverde et al., 2002). Utilizing the TIMSS framework, the measure of cognitive challenge used in this analysis was the average level of difficulty based on classifying tasks on a scale of 1 (least challenging) to 4 (most challenging). While this measure is also compared across courses and years, it is not scaled to allow estimation of cumulative learning opportunities like the other two measures of curriculum content.

The overall measure of curriculum *quality* combines these two independent dimensions by giving more relative weight to topics associated with challenging tasks in estimating the amount of instructional material in a textbook. For example, long books filled with mostly drill and practice exercises would have a lower value on this indicator of curriculum material than even a shorter book with exercises requiring highly sophisticated problem solving skills (see Schiller et al., 2007 for how this indicator was calculated). Higher values on this variable reflect that more cognitively challenging exercises would take more time for students to complete and provide more opportunities to learn for the same amount of less cognitively challenging material (Schmidt et al., 2001). As with the measure of curriculum quantity, this indicator of quality is scaled to have a mean of 1 (considered a year of curricular material) and a standard deviation of .25 (half of a semester). The standardized nature of this curriculum quality indicator allows comparisons across courses and years, permitting estimation of accumulation of differences during high school. Over the four years of high school, students accumulated an average of 3.4 years of quality curriculum with a standard deviation of .87.

Analytical Approach

The analysis to answer the first research question is descriptive, showing variations in the quantity and level of cognitive challenge of instructional material in students' mathematics courses each year in high school. The remaining analyses examine (1) whether traditional measures of course or credit counts tend to underestimate differences in opportunities to learn mathematics at the end of high school and (2) how differences in learning opportunities accrue at varying rates over the four years of high school. For these we utilize versions of hierarchical linear modeling (HLM) to estimate differences in learning opportunities related to students' socio-demographic and academic backgrounds (Raudenbush & Bryk, 2002). HLM allows simultaneous modeling of variation in a dependent variable at more than one level of analysis—students within schools for the first analytical question and years within students within schools for the second. All of the independent variables were grand-mean centered to improve model estimation.

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¹⁰A textbook that contained chapter review questions incorporating more than one topic was considered to contain more instructional material than a textbook of similar length in which review questions dealt with only one topic.

RESULTS

Describing Annual Differences in Curriculum Content During High School

Our analyses begin with an examination of the relationship between mathematics track and learning opportunities in students' courses each year in high school. The top panel of Figure 1 shows differences in quantity of instructional materials in textbooks adopted for students' courses by year for each track. The center boxes show the 95% confidence intervals for the mean quantity of curriculum for that group, with the high and low marks reflecting plus and minus one standard deviation (or the range within which approximately two thirds of cases fell). Given the scaling of the curriculum quantity indicator, basic track students had textbooks averaging a little over three quarters (.78) of a year's worth of instructional material in 9th grade compared to on average more than a year's worth (1.15) for advanced track students in the same grade. This average difference of .36 translates into almost three quarters of a semester of instructional material. Differences within tracks were also substantial, especially among basic track students with over a semester (.5 of a year) of instructional material separating those one standard deviation above and below the mean in most years. Thus, although higher tracks tended to provide students with greater amounts of instructional material, the differences in learning opportunities within tracks were also pronounced.

Just comparing quantity of instructional material, however, fails to recognize that curriculum also differs in the types of tasks presented students. The second panel in Figure 1 shows the differences between and within tracks in the average level of cognitive challenge in students' textbooks. Students' textbooks appeared to focus on basically low-level skills—for example, simple recollection of facts, routine procedures, and recognizing vocabulary (level 1) or complex procedures, communicating relationships, and describing results (level 2). Only advanced track students in their senior year tended to have textbooks with significant amounts of mid-level skills—for example, formulating problems, verifying results, developing notation, and critiquing (level 3). As with curriculum quantity, not only did higher track students tend to have more challenging material in their textbooks but also variations in the level of cognitive complexity within tracks were of similar size, if not larger.

The bottom panel in Figure 1 shows differences between and within tracks in overall curriculum quality based on variations in the quantity of more or less challenging instructional material in students' textbooks. Each year, basic track students tended to have textbooks with smaller amounts of quality curriculum (approximately .81 to .85 of a year) compared to those in other tracks. However, variations in curriculum quality were found within all tracks with close to a semester's worth of instructional material separating students in courses one standard deviation below and above the mean in at least one year. Thus, while students' mathematics tracks shaped their access to quality curriculum, other factors likely also contributed to differences in accumulated learning opportunities by the end of high school.

Estimating Accumulated Learning Opportunities During High School

Before modeling how gaps in accumulated curriculum quality develop over time, we first compare the new measure of quality curriculum to three traditional indicators of exposure to mathematics during high school. Two of these measures—number of years in which mathematics courses were taken and number of semesters worth of mathematics courses—are the most basic measure of students' learning opportunities because if they are not enrolled in any course, then learning a subject like mathematics is unlikely. The third, number of Carnegie units, provides a somewhat more fine-grained measure of learning

opportunities by taking into account the number of hours the class met but is available for only those students who earned passing grades in the course. All of these variables are scaled such that 1 is defined as a year. Preliminary analyses showed that the large majority of variation in students' potential exposure was related to individual differences (between 77% for years enrolled to 65% for semesters enrolled of the total variation) rather than the school attended (between 23% and 35%, respectively, of the total variation).¹¹ The change in deviance in Table 1¹² indicates that mathematics track, student socio-demographic backgrounds, and school characteristics combined to explain statistically significant amounts of variation in the outcomes. In addition, between 7 to 13% of the variation related to individual differences and around 18% to 29% of variation related to school differences were accounted for by these variables (see Luke, 2004 for how these pseudo- R^2 statistics were calculated).

First, controlling for socio-demographic differences, students' mathematics tracks were related to differences in learning opportunities accumulated during high school. Basic mathematics track students were consistently disadvantaged relative to those in the other tracks, but the size of the estimated differences varied across the dependent variables. Counting the number of years or semesters of course enrollments indicated a difference of around .6 of a year, but the number of Carnegie units and curriculum quality indicated a gap of around .9 of a year. Thus, simply counting years or semesters enrolled may underestimate gaps in mathematics exposure across tracks by almost a third. In general, no differences were found between the other three tracks with one exception—advanced track students tended to earn more Carnegie units than those in other tracks, which may reflect their greater likelihood of earning passing grades.

Second, estimates of disparities related to differences in socio-demographic backgrounds varied somewhat based on the outcome being predicted. Compared to the other measures, Carnegie units showed the largest advantages for students who had more educated parents, were females, or lived with both natural parents. On all measures of learning opportunities, both Asian Americans and African Americans appeared relatively advantaged compared to Whites. While initially surprising, the female and African American advantages only become apparent when comparing students in the same mathematics tracks; thus, in absolute terms these groups are not advantaged overall.

Finally, school size and graduation requirements in mathematics were not significant predictors of any of these learning opportunities. In addition, location was generally not related to any of these outcomes with one exception: students attending rural schools tended to accumulate almost a quarter of a year (half of a semester) less quality curriculum compared to those attending suburban schools.

Comparing Curriculum Quality Trajectories During High School

Instead of differences in learning opportunities accumulated by the end of high school, in these final analyses we use the more fine-grained nature of curriculum quality to examine how gaps develop during high school. For this purpose, we examine students' academic careers as series of educational experiences spanning the high school years using 3-level hierarchical linear growth models to show the rates at which the gaps develop over time (Raudenbush & Bryk, 2002). Preliminary analysis indicated that the rate of accumulating quality curriculum was not constant across years, which is accounted for in this analysis by

¹¹These estimates are from an unconditional HLM model (i.e., one without any independent variables) that is equivalent to a one-way analysis of variance with the "treatment" being school attended.

¹²A table containing the standard errors, not shown here due to space considerations, for the coefficients is available from the contact author.

estimating coefficients for year and year-squared (see Appendix for explanation) in high school. Once taking into account differences simply due to the passage of time, preliminary analyses indicated that about 56% of the variation in accumulated quality curriculum each year was related to individual student differences and about 35% was attributable to differences across schools, with the remaining approximately 9% due to deviations from the average growth trajectory. Including mathematics track, students' socio-demographic and school characteristics in the analysis produced statistically significant improvement in fit and accounted for an additional 9.9% of the variation related to time, 10.1% of the variation related to student differences, and 15.8% of the variation we found across schools.

The first row in Table 2 contains the coefficients describing the average students' trajectory in accumulating quality curriculum during high school using three parameters: an intercept indicating the expected years of quality curriculum at roughly the middle of high school and the two "year" coefficients to describe a growth curve that was steeper in the early years of high school but tended to level off in the later years. Using procedures described in the Appendix, the average student would be expected to have accumulated .960 of a year of quality curriculum as a freshman, 1.981 as a sophomore, 2.781 as a junior, and 3.360 by the end of high school.

The rest of Table 2 examines how variations from this typical trajectory related to student and school characteristics. The next three rows of coefficients indicate that the regular track students (contrast category) tended to follow different curriculum quality trajectories from those in other tracks. The first column indicates that, controlling for the other socio-demographic and academic factors, students in the lower two tracks (Basic and Low-regular) tended to have accumulated less quality curriculum by the middle of high school than their counterparts in the two higher tracks (Regular and Advanced). The coefficients in the remaining two columns indicate that the growth trajectories for the three non-regular track students tended to be flatter in the early years and steeper in the later years compared to the typical trajectory described earlier. These trends are depicted in the top panel of Figure 2, which compares the expected accumulated quality curriculum for basic, low, and advanced tracks to that of the regular track after adjusting for the other factors included in the analysis. In general, differences in amounts of quality curriculum freshman year were relatively modest—about a quarter of year between those in low regular and advanced tracks. During the remaining three years of high school the differences in accumulated curriculum between the two highest tracks tended to be relatively small—less than .04 of a year. In contrast, the differences between students in the regular track and in the low regular track grew from around .114 of a year as freshmen to about .341 of a year as juniors, with a slight closing of the gap to .262 of a year in their senior year. Most striking, however, was the steady pace at which basic track students dropped behind their regular mathematics track schoolmates. By the end of high school, basic track students had accumulated over .811 of a year less curricular material than regular track students. Thus, what started out as modest differences in the first year of high school became dramatic differences by the end of high school.

The students' initial position in the high school mathematics sequence, however, is only part of the story as their individual characteristics also appear to be related to curriculum quality trajectories even after taking into account their mathematics track. The lower panel in Figure 2 shows that, while the differences freshman year are basically non-existent, gaps in accumulated quality curriculum related to parents' education level tended to steadily grow across high school. By senior year and net of the other variables, the estimated difference between a student whose parents graduated from college and a similar student whose parents only graduated from high school was about .146 of a year.¹³ While relatively small, this statistically significant gap is estimated for students in the same mathematics tracks, which is also related to parents' education level, and developed in only four years.

Differences in accumulation of quality curriculum were also related to students' family structure and race or ethnicity. Students from two-parent families generally were exposed to greater amounts of quality curriculum during high school, but the rates of accumulation were not statistically significantly different from those from non-traditional types of families. Controlling for mathematics track and family background, Latino/as tended to lag behind Whites due to much flatter growth trajectories while both Asian Americans and African Americans tended to accumulate quality curriculum at a faster rate as juniors and seniors as compared to Whites. While not shown in Table 2, when mathematics track is not included in the model, the difference in accumulated quality curriculum between African American and Whites was not statistically significant.

Finally, Table 2 indicates that curriculum trajectories also differed by the types of schools that students attended. Rural school students tended to consistently lag about .162 of a year behind their suburban school counterparts across the four years of high school. In contrast, urban school students tended to accumulate quality curriculum at faster rates than suburban school students during the early years of high school but then lost ground during the last year. At its largest in the junior year, the gap in accumulated curriculum quality between urban and suburban schools was about .145 of a year. Students in large schools tended to accumulate quality curriculum at similar rates as those in other schools except for the last two years of high school when their exposure did not level off as quickly as their counterparts in other schools. Conversely, students in schools with a greater emphasis on mathematics in their high school graduation requirements tended to have greater exposure to quality curriculum but accumulated these learning opportunities at a similar rate as in other schools.

LIMITATIONS

In this article we make no judgments about what constitutes a sufficiently high quality curriculum to promote student mastery of the subject matter content intended for their courses. Unfortunately, we cannot test the potential academic benefits of having higher quality curriculum, as the dataset used here does not include any standardized measure of students' mathematics knowledge. However, other studies suggest that students who receive a higher quality curriculum—characterized not only by the amount of material but also by the challenges presented to students when engaging with that material—are more likely to learn the desired topics and skills (Gamoran et al., 1997; Schmidt et al., 2001; Tornroos, 2005). Thus, our findings support arguments that differences in learning opportunities may be a major contributor to persistent gaps in mathematics achievement.

While an improvement over conventional studies, our analyses are still likely to be underestimating disparities in a particular year or accumulated over time. Most importantly, the dataset used has no indicators of teacher quality or pedagogy that other studies suggest influence curriculum implementation. Teachers may have deviated from the textbook by, for example, skipping some chapters in order to increase time to cover other topics. In contrast, other teachers might have spent greater amounts of time on early review chapters to make sure students had the desired foundational skills and knowledge. However, we expect that how well the textbook's content fit the perceived needs of students assigned to a course was a factor in its selection (Tarr et al., 2006). In addition, weaker and less experienced teachers tend to be more dependent on textbooks for instructional material, which they may even use to teach themselves the material before teaching it to their students (Boaler & Staples, 2008; Stein & Kim, 2008; Tornroos, 2005; Valverde et al., 2002). Given that these teachers are

¹³These two groups—students whose parents only graduated from high school and those whose parents graduated from college—are approximately two standard deviations apart on the indicator of parents' education level.

more likely to be assigned to lower track classes (Oakes, 2005) and those with higher numbers of academically disadvantaged students (Callahan, 2005), some groups may be doubly disadvantaged in having teachers less likely to compensate for the lower quality textbooks that our results indicate tend to be adopted for their courses.

DISCUSSION AND CONCLUSIONS

Our findings suggest that important, yet hidden, disparities may be present in high school mathematics courses that are not reflected by conventional measures of high school course taking. The probabilistic estimates of curriculum quality used in this article highlighted that, in general, students in lower-level mathematics tracks tended to receive lesser amounts of cognitively challenging instructional material in their courses than those in regular or advanced tracks. While some of these accumulated gaps at the end of high school may be due to lower track students not enrolling in mathematics courses as seniors, we also found significant gaps in curriculum quality between mathematics tracks across courses taken senior year. In addition, differences in the number of years or semesters of mathematics course enrollments were smaller than those related to curriculum quality. Thus, lower track students were not only lagging behind in the mathematics course sequence but also getting fewer opportunities to learn the material being covered in the courses in which they did enroll.

While mathematics track was a strong predictor of curriculum quality, variations in curriculum quality essentially occurring within tracks each year were also related to students' socio-demographic backgrounds and school characteristics. Small annual differences in curriculum quality developed into significant gaps between students from varying social class backgrounds by the end of high school. These disparities in learning opportunities during high school were most likely piled on top of already large differences accumulated during the first nine years that students were in school (Alexander et al., 1997). Net of students' ability or prior achievement, more educated parents appear able to get their children placed in higher level mathematics courses (Hallinan, 1991; Schiller & Hunt, in press; Smith, 1996; Stevenson, Schiller, & Schneider, 1994) and ensure that these courses, or others their children take, have a higher quality curriculum (Gamoran et al., 1997; Oakes, 2005). Our results are consistent with concerns that these dual influences on learning create self-fulfilling prophecies through fewer opportunities to engage in problem solving and other cognitively challenging activities for the children of less educated parents.

While not directly addressed in these analyses, mathematics track incorporates a third dimension of curriculum (subject matter content) that contributes to inequity. Even if similar in quantity of instructional material and level of cognitive challenge, a geometry course exposes enrolled students to very different topics from those in an Algebra 2 course. While possibly accumulating similar amounts of course credits and quality curriculum in high school, African Americans and Latino/as tend to lag behind Whites and Asian Americans through the mathematics course sequence (Kelly, 2009; Riegle-Crumb, 2006; Schiller & Hunt, in press). While the roots of these disadvantages lie in the earlier grades, addressing them in high school would reduce disparities related to race/ethnicity in science and technical fields. Regardless of the subject matter content being covered, sustained engagement in cognitively challenging activities should be a feature of every course.

This study highlights how disparities in learning opportunities are the product of course enrollments *and* curriculum content such that the process of being "left behind" develops both gradually and perniciously over time. However, some schools offer quality curriculum to all students, managing to reduce disparities in learning opportunities while also maintaining high standards (Gutiérrez, 1999; Silva & Moses, 1990). Thus, increasing equity

while maintaining excellence will require similar commitments from schools and teachers to provide all students with access to quality curriculum in whichever courses they enroll. Curriculum leaders can be proactive in using the textbook selection process as an opportunity to focus attention on quality and effectiveness in developing a coherent mathematics program with high expectations for all students (Mark, Spencer, Zeringue & Schwinden, 2010). In evaluating potential textbook adoptions, considerations should include not only the quantity and cognitively challenging nature of the instructional content but also support and resources available to for effective implementation of that curriculum (Hudson, Lahann, & Lee, 2010). Finally, given the current tight fiscal climate, teachers may need assistance with supplementing more limited and/or less challenging curriculum when purchasing new textbooks is not an option.

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Biographies

Kathryn S. Schiller is associate professor in the Departments of Educational Administration and Policy Studies and of Sociology and an Associate of the Center for Social and Demographic Analysis at the University at Albany, State University of New York. Her research focuses on stratification, academic trajectories, and school transitions.

William H. Schmidt is University Distinguished Professor at Michigan State University, co-director of the Education Policy Center, director of the NSF PROM/SE project, and holds faculty appointments in the Departments of Statistics and Educational Psychology. His current research concerns issues of academic content in K-12 schooling, assessment theory and the effects of curriculum on academic achievement.

Chandra Muller is professor of Sociology at the University of Texas at Austin. Her current research focuses on the role of high school course taking in preparation for higher education and in the transition to adulthood.

Richard T. Houang is the Director of Research for the NSF PROM/SE Project and the Institute for Research on Mathematics and Science Education at Michigan State University. His substantive interests include curriculum assessment, the study of the relationship between mathematics and science curriculum and student achievement, item characteristics and student performance, causal modeling, domain-referenced and classroom assessment.

APPENDIX CALCULATING GROWTH TRAJECTORIES

Most growth curve models include at least three parameters to describe differences over time in the rate of accumulating the outcome. To facilitate interpretation of the estimated coefficients from these complex models, we used the results in Table 2 to calculate the expected accumulated quality curriculum for each year in high school. For example, we used the following to calculate the expected accumulated quality curriculum by the end of freshman year:

$$\begin{aligned} \text{Quality Curriculum}_{ij} &= \gamma_{000} + (\gamma_{100} * \text{year}_t) + (\gamma_{200} * \text{year}_t^2) \\ .960 &= 2.270 + (1.351 * 1.5) + (-.110 * 6.5) \end{aligned}$$

Because all the variables were centered around their grand means to improve estimation of the intercept (γ_{000}), the time values used for calculating the estimate above are differences the mean of 2.25 for “year” and 7.5 for “year².”

The coefficients (often called cross-level interaction effects) for student and school characteristics in Table 2 are adjustments to the baseline above. The estimated gap in curriculum quality between basic and regular track freshmen, net of the other variables in the model, was calculated as follows:

$$\begin{aligned} \text{Basic} - \text{Regular Track}_{ij} &= \gamma_{030} + (\gamma_{130} * \text{year}_t) + (\gamma_{230} * \text{year}_t^2) \\ -.112 &= -.510 + (-.475 * 1.5) + (.048 * 6.5) \end{aligned}$$

The value for each parents’ education level was subtracted from the mean (3.63) for the sample when calculating deviations from the typical trajectory the bottom panel of Figure 2. Net of the other variables, the estimated gap in curriculum quality by the end of high school between a student whose parents only graduated from high school (value = 2) and those with average parents education was calculated as follows:

$$\begin{aligned} \text{Low} - \text{Average Parents Ed}_{ij} &= (\gamma_{040} * \text{Pared}_{ij}) + ((\gamma_{140} * \text{Pared}_{ij}) * \text{year}_t) + ((\gamma_{240} * \text{Pared}_{ij}) * \text{year}_t^2) \\ -.079 &= (.019 * 1.63) + ((-.006 * 1.63) * 1.5) + ((.005 * 1.63) * 6.5) \end{aligned}$$

Figure 1.
Quantity, Level of Cognitive Challenge, and Quality Curriculum by Math Track

Figure 2.
Estimated Differences in Accumulation of Quality Curriculum across High School

Table 1

Two-Level HLM Estimates of Differences in Total Opportunities to Learn Mathematics.

	# of Years	# of Semesters/2	# of Carnegie Units Earned	# of Quality Curriculum
Intercept	3.242 ***	3.551 ***	3.184 ***	3.335 ***
Math Track ^a				
Advanced	-0.048	0.025	0.285 **	0.053
Low Regular	0.011	-0.003	-0.081	-0.176
Basic	-0.579 ***	-0.639 ***	-0.964 ***	-0.894 ***
Family Background				
Parents Education Level	0.037 **	0.053 **	0.076 ***	0.049 ***
Female	0.016	0.029	0.194 ***	0.022
Two-Natural Parent Family	0.111 **	0.158 **	0.266 ***	0.130 **
Race/Ethnicity ^b				
Latino/a	-0.078	0.039	-0.069	-0.058
African American	0.232 ***	0.369 ***	0.267 **	0.264 ***
Asian American	0.183 *	0.310 **	0.367 **	0.233 *
Other Race/Ethnicity	0.066	0.052	0.004	0.011
School Characteristics				
Location ^c				
Urban	0.012	0.089	-0.246	0.088
Rural	-0.093	0.031	0.135	-0.230 *
Large School	0.049	0.073	-0.120	0.178
Math Grad. Requirements	3.009	5.938~	-0.453	3.042
Model Fit Statistics				
Change in deviance	132.933 ***	127.825 ***	348.34 ***	220.31 ***
AIC	7715.307	9690.011	9854	8284
R2-Level 1	0.065	0.086	0.113	0.116
R2-Level 2	0.157	0.180	0.159	0.252

Note: Number of students (level 1) = 3,523; Number of schools (level 2) = 108.

^aContrast category is Regular Track^bContrast category is White^cContrast category is Suburban

~ p < .10

* p < .05

** p < .01

*** p < .001

Table 2**Modeling Accumulation of Curriculum Scope Per Year in High School**

	Intercept	Year	Year[*] squared
Intercept	2.270 ***	1.351 ***	-0.110 ***
Math Track ^a			
Advanced	0.051	-0.211 **	0.036 *
Low Regular	-0.252 ***	-0.371 **	0.064 **
Basic	-0.510 ***	-0.475 ***	0.048 *
Family Background			
Parents Education Level	0.019 ***	-0.006	0.005 *
Female	0.003	0.044	-0.008
Two-Natural Parent Family	0.055 **	-0.006	0.008
Race/Ethnicity ^b			
Latino/a	-0.028	-0.139 **	0.027 *
African American	0.047 *	-0.034	0.017 *
Asian American	0.064 **	-0.138 *	0.039 **
Other Race/Ethnicity	-0.105	-0.093	0.004
School Characteristics			
Location ^c			
Urban	0.089	0.227 **	-0.038 *
Rural	-0.162 *	-0.030	-0.002
Large School	0.059	-0.123	0.037 *
Math Grad. Requirements	2.163 *	1.549	-0.130
Model Fit Statistics			
Change in Deviance	749.09 ***		
AIC	2177		
R2-Level 1	0.099		
R2-Level 2	0.101		
R2-Level 3	0.158		

Note: Number of students (level 2) = 3,523; Number of schools (level 3) = 108.

^aContrast category is Regular Track

^bContrast category is White

^cContrast category is Suburban

* p < .05

** p < .01

*** p < .001