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Recent Trends in Preparing Ethnic Minorities for Careers in Mathematics and Science

Richard Brown

D. Michael Campbell

University of Southern California

Abstract: This study compares trends in participation and performance on mathematics and science Advanced Placement exams for student ethnic subgroups in California high schools over a 6-year period. Results indicate that although growth in participation and performance is evident for all subgroups, the rates of increase differ across groups. As minority participation improves more slowly than the participation of other ethnic subgroups, there will be a continued lack of minorities in mathematics and science careers.

Resumen: Este estudio compara por subgrupo étnico las tendencias en la participación y la ejecución de matemáticas y ciencias en exámenes de asignatura avanzada en las secundarias de California a través de un período de 6 años. Los resultados indican que aunque el crecimiento en participación y ejecución es evidente en todos los subgrupos, los incrementos difieren a través de los grupos. Debido a que la participación minoritaria mejora más despacio que la participación de otros subgrupos étnicos continuará existiendo una falta de estudiantes minoritarios en las carreras de ciencias y matemáticas.

Keywords: *Advanced Placement testing; math and science achievement; ethnic differences; California*

A renewed focus on mathematics and science achievement is of immense importance to current and future generations of students in the United States. It has been argued that decades of inadequate preparation in mathematics and science have created a deficit of qualified workers and will continue to generate a widening disparity for the United States in the global industrial workplace.

Possible solutions to this problem may be found by looking into the educational pipeline at the elementary, middle, and high school levels. In particular, middle schools play a predominant role in assuring that students not only have mastered basic computation but are also developing the mathematical thinking and problem-solving skills important in the mathematics courses they will take in high school and college (Brennan, 2003). Science literacy is of equivalent importance during early and formative educational years (Oakes, 1990). Research suggests that higher

expectations, challenging assignments, cooperative learning opportunities, high-engagement teaching strategies, and the presence of guidance and advisement programs lead to higher enrollments in advanced level coursework at the high school level (Cooney & Bottoms, 2003).

Not only are many students inadequately prepared in mathematics and science, but research is finding that they are not prepared equally (Herzig, 2004; Johnson, 2000; Ziegler & Heller, 2000; Zohar & Sela, 2003). Solorzano and Ornelas (2002) detailed the problems with educational parity when they examined Chicana/Latina Advanced Placement (AP) students and found that even when Latino/a students attend schools with high AP enrollments generally, they are not equitably represented. Similarly, poor school districts, typically rich in ethnic minority students, offer far fewer AP courses with even fewer students scoring proficient or better on AP exams (Furry & Beasley, 1999; Furry & Hecsh, 2001; Ratliff, 2001; Rinne, 2001). Furthermore, Oakes (1990) found in a national study that minorities, especially in inner cities, have considerably fewer opportunities to learn advanced math and science than their White counterparts.

The literature on minorities in mathematics and science education is frequently analogous to that of women in these fields. For decades, minority men and women have been largely absent from advanced high school coursework, college classes, graduate work, and subsequent careers in math and science. With growing numbers of minorities in U.S. public school systems, the issues of adequate preparation and equal participation are at the forefront of many research agendas in the fields of education. In terms of minority participation in math and science, some interesting trends have occurred in states where minority population numbers are increasing. Teranishi, Walter, and Soloranzo (2004) remark that in states like California, minorities will soon be the majority. For instance, in 2000, Latinos, Asian Americans, and African Americans represented 49.1% of the total population in California; by 2010, their proportion is expected to increase to 54.6% (p. 2224). With this swelling in sheer student numbers, one would rationally conclude that more students of color would be involved in more mathematics and science courses. Decades of research have presented a different view on the matter. In spite of the magnitude of America's public school system, inequitable treatment and participation for minority students still persist at all levels of education. In the middle and high school years, minority students face a number of factors that hinder participation in math and science. Some of these factors include a lack of educational resources and poor facilities (Hornig, 2005; Solorzano & Ornelas, 2004; Teranishi et al., 2004), poorly trained teachers (Hornig, 2005; Teranishi et al., 2004), and language barriers (Hampton & Gallegos, 1994). Each of these factors has been shown to reduce the number of minority children continuing in the educational pipeline from high school to college and then on to careers in math and science.

As mathematics is the basis for understanding and continued achievement in science, much of the minority student literature in math and science highlights the need

to integrate the two at early levels of students' educational experiences (Cooney & Bottoms, 2003; Hrabowski, 2003; Oakes, 1990, 2004; Olszewski-Kubilius, Lee, Ngoi, & Ngoi, 2004). Preparing minority students for continued achievement and participation in math and science creates a pipeline of qualified and active students who go on to pursue careers in these fields. However, research has shown evidence that this pipeline is repeatedly blocked as minority students have very few mentors, role models, and tangible examples of successful individuals of color showing them that there are real possibilities for success in math and science careers (Brown, 2004; Stevens, 1993, cited in Munoz & Clavijo, 2000). To further illustrate this blockage of minority students progressing into such fields, Murphy and Sullivan (1997) found that non-Asian minorities (African Americans, Latinos, and Native Americans) represented 20% of the total population of the United States but less than 7% of the employees in science, mathematics, and technology-related careers in the mid-1980s. What's more, 20 years later, the trends have not substantially improved. According to Campbell, Jolly, Hoey, and Perlman (2002), African Americans make up approximately 12% of college freshmen and almost 10% of engineering freshmen nationwide. However, African Americans make up less than 5% of employees in mathematical and computer sciences and less than 4% of workers in engineering, physical sciences, and economics.

Parental involvement and cultural expectations play a significant role in the preparation and participation of students in math and science. The research is replete with studies focused on minority student achievement in mathematics and science as a function of parental involvement (Brian, 1994; Kreinberg, 1982; Landerholm, Rubenstein, & Losch, 1994; Pearson & Fechter, 1994; Teranishi et al., 2004; Walker, MacGillivray, & Aguilar, 2001). A similar amount of research is available on cultural expectations (Li, 2004; Walker et al., 2001; Xu, 1999). Similarly, Ferry, Fouad, and Smith (2000), building on the work of Lent, Brown, and Hackett (1994), found that parental involvement and encouragement in math and science was a significant influence on student learning experiences. From these learning experiences, students were found to have increased self-efficacy and outcome expectations. In another example, Kerr and Robinson-Kurpius (2004) highlight that many Hispanic students are expected to stay close to home, support family objectives, and adhere to cultural ideals. In the same way, African American students often lack the social support and educational self-efficacy necessary to persist in math and science majors (Gloria et al., 1999, cited in Kerr & Robinson-Kurpius, 2004). The current body of literature provides strong connections to the fact that a student's culture plays a significant role in his or her preparation and participation in math and science coursework.

In addition to the level of a student's parental involvement and the role of cultural expectations, one way of indicating mathematics and science preparation is student participation in AP courses and test taking. Established by the College Board in 1955, the AP program was designed to test a high school student's ability to perform scholastically at the college level. AP classes include a college subject matter

curriculum designed for high school level students, which culminates with an optional exam (AP exam) scored on a scale from 1 to 5, with 5 being the highest. Students earning a score of 3 or better on these examinations may qualify for college course credit at many colleges and universities. The College Board, a not-for-profit membership association whose mission is to connect students to college success and opportunity, is responsible for the development and scoring of the curriculum and exams. As nearly six decades have passed since its inception, the program has grown to include more than 35 exams in 20 different subject areas with the vast majority of the students taking exams in U.S. history, English literature and composition, Spanish, calculus AB, U.S. government and politics, and biology (Furry & Hecsh, 2001).

Although many factors persist as to why minority participation and preparation in AP mathematics and science are below that of other subgroups, the importance of AP testing is on the rise. One reason, and perhaps the most significant, is the competitive nature of college admissions for in-state colleges and universities. Students who complete multiple AP courses with satisfactory grades find their prospects of obtaining admissions to selective schools increased. In addition, students are able to shorten their time and the amount of tuition paid to colleges and universities by earning college credit while still in high school (Santoli, 2002). Furry and Hecsh (2001) found that school systems have an incentive to provide as many AP classes as the schools' infrastructures (qualified teachers, classrooms, and curricula) can support. Schools can attract parents and students by offering the highly valued AP courses, whereas some families might otherwise opt for private schools with similar student populations. Similarly, AP courses provide teachers the opportunity to teach material not usually covered in typical high school curricula. Thus, many teachers are excited to be involved in and sometimes initiate AP courses in their academic fields. What's more, motivated students in AP classes provide teachers with optimal teaching environments where both students and teachers grow intellectually.

Across the full array of subject matter offerings in high school, AP testing is on the rise (Brown, 2004). With the increased growth in AP courses and test taking has come decreased parity for certain groups of students. Recent research has pointed out substantial gaps in equal preparation and participation of gender and ethnic minority subgroups to AP curriculum and test taking. Contreras (2005) found that "access to AP courses remains disparate for underrepresented students" (p. 208). The author goes on to further illustrate that Latino students continue to lag behind their White and Asian American counterparts in access and achievement. Furry and Hecsh, in their 2001 report, *Characteristics and Performance of Advanced Placement Classes in California*, provide complementary evidence that ethnic participation, especially for African Americans and Hispanics, did not proportionally change from 1999 to 2000. In essence, although the quantity of minority subgroups is growing, the percentage of minority students taking all AP courses has not grown at a comparable rate. In addition, schools in urban or socioeconomically disadvantaged areas have been found to offer fewer AP courses than other more affluent, suburban areas (Klopfenstein, 2004; Solorzano & Ornelas, 2002; Trounson & Colvin, 2002).

As a result of the inequalities in AP access for minority students, the American Civil Liberties Union (ACLU) filed suit against the state of California alleging that AP course offerings in Inglewood High School (a high school in urban Los Angeles) were inadequate. As a result of this suit, the California Department of Education commenced the AP Challenge Grant program, designed to increase the availability of and participation in AP courses for minority students in California high schools (Brown, 2004). Whether or not these inequalities have been resolved or mitigated by recent trends is a question driving this investigation.

This study is designed to address two objectives. The first is to compare the extent to which opportunities to take mathematics and science AP exams are increasing or decreasing for student subgroups. We do so by examining 6 years of student testing data and identifying features of high schools that relate to greater expansion in AP test taking for minority groups in these areas. The second is to compare changes in performance on AP tests in mathematics and science for each of these subgroups and identify what features of schools influence these changes in student performance.

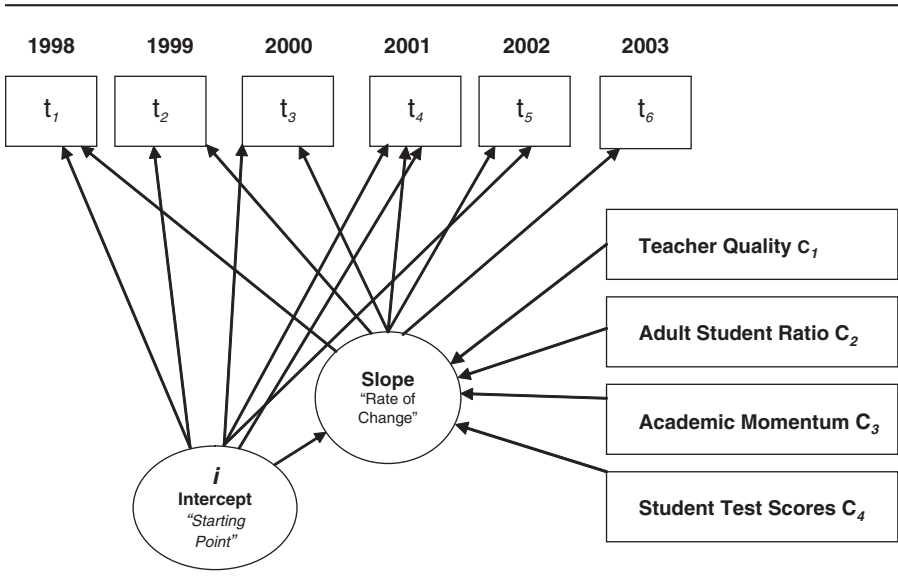
Method

In describing change, the form of change must be identified. Change may be linear—going up or down in a straight line—or it may be nonlinear—going up rapidly and then leveling off or accelerating its pace of improvement (Acock & Fuzhong, 1999). For our analyses, we begin with a linear growth model with covariates to explain the rate of change in AP test taking and performance. However, in some instances, it may be necessary to amend the linear model to include a nonlinear component to improve the explanatory capability of the model and improve the model's fit to the observed data.

The starting point for change over a given time period is the intercept (i), the beginning value of our data set in year 1 (1998). Indicators t_1 through t_6 depict the data set years ranging from 1998 to 2003. In addition to the intercept, the linear slope describes the amount of change for each measured variable and illustrates the degree to which the curve grows each year (Acock & Fuzhong, 1999). Other variables—specifically, covariates may affect the rate of change and consequently give insights into what conditions at the school might relate to varying levels of change—are depicted by the indicators C_1 through C_4 .

The school level covariates used in this study include teacher quality, adult–student ratio, school academic momentum, and student test scores (see Figure 1). The covariate teacher quality (C_1) is measured by the percentage of fully credentialed teachers in each school. The covariate adult–student ratio (C_2) is measured by the ratio of students to teachers and the ratio between administration and staff to students. The covariate academic momentum (C_3) is a measure of a school's improvement in proficiency rates on state assessment tests. The covariate student test scores (C_4) is measured by how well students are doing, as measured by their state test scores.

Figure 1
General Latent Variable Growth Model



The relationship between the intercept and the slope is estimated in this latent variable growth model and represented by a line starting from the intercept and continuing to the slope. Positive values for this relationship reflect faster growth rates for schools with more AP testing in the initial year 1998. Negative values reflect slower growth rates for schools with higher levels of student test taking in that same year.

Data Set

The AP testing data used in this study include information for all AP tests taken by California high school students from 1998 to 2003. The data were disaggregated by subject area, ethnicity, and school site for all 6 years. The complete data set included 16,383 records from 874 high schools in 13 AP subjects.

Results

Model Fit

The process of interpreting the estimates derived from the proposed models entails identifying how well the models adequately capture the variability in the data.

This is usually done through the investigation of a variety of statistical measures of model fit. One measure of model fit is the root mean square error of approximation (RMSEA). This metric ranges from a value of 0 to 1, with lower values indicating better model fit. Several researchers have suggested threshold values for the RMSEA indicating sufficient fit of the model to the data. Hu and Bentler (1999) propose .06 as an optimal critical value for indicating close fit. Browne and Cudeck (1993) suggest that values ranging from .06 to .08 indicate acceptable fit and values ranging from .08 to .10 indicate mediocre fit. RMSEA values above .10 would reflect a poor fitting model. Whereas the linear models using the performance data indicated very good fit, the linear models using the participation data as outcomes for some of the ethnic groups generated fit statistics beyond the acceptable thresholds. To address this and provide better fit of the models to the data, a quadratic growth term was added to the models with the participation data as the outcome variable. This allows the growth trajectories to be nonlinear, or level off or accelerate over time. This addition resulted in better explanatory power of the models and fit statistics within the acceptable limits.

Participation

The first research question investigated reflects a primary interest in the slope segment of this research model. Each slope value illustrates whether the opportunities in mathematics and science are increasing or decreasing for each ethnic group examined in this study. The higher the slope value for each subgroup, the faster this group is growing in mathematics and science participation. The lower the slope values, the slower each subgroup is increasing participation in AP mathematics and science testing. When the slope values are compared in relation to each subgroup, meaningful testing trends can be determined. The growth data that address this research question are located in the third column labeled "Linear Slope" in Table 1 and are graphically displayed in Figure 2 for science and Figure 3 for mathematics.

All subgroups are taking more tests each year, so the growth rates are positive for all subgroups. However, not all groups are growing at the same rate, nor do they have the shape to their trajectories. Those groups that started out taking fewer tests showed slower growth than the groups that started out taking more tests. The findings suggest that AP opportunities in mathematics and science are continuing to increase for those groups who have traditionally participated in AP tests. Thus, taking more tests appears to influence the pace of growth rates. Therefore, although opportunities are increasing for all subgroups, the gaps between traditionally advantaged and recurrently disadvantaged groups are continuing to widen.

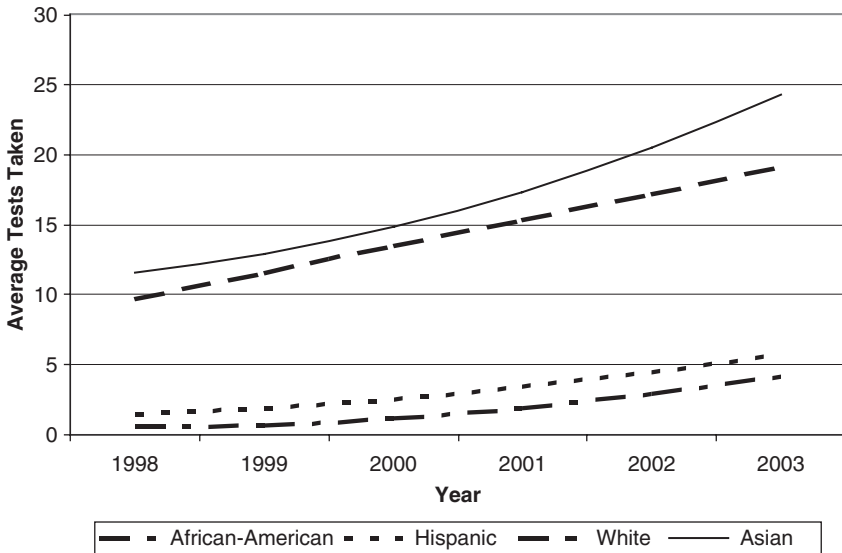
When comparing the extent to which AP opportunities are increasing or decreasing in mathematics and science for ethnic subgroups, the following trends can be observed: (a) All ethnicities, on average, have higher intercept and slope figures in mathematics compared with science; (b) African Americans, on average, have the lowest intercept and slope data in both mathematics and science, meaning that this

Table 1
Ethnic Subgroup Participation in Mathematics and Science

Subgroup	RMSEA	Intercept	Linear Slope	Quadratic Slope	Teacher Quality	Adult-Student Ratio	Academic Momentum	Student Test Scores
Math								
White	.054	11.51	2.945	0.076	<i>ns</i>	.212	<i>ns</i>	.959
African American	.046	.512	.411	-0.091	<i>ns</i>	.069	<i>ns</i>	<i>ns</i>
Hispanic	.054	2.136	.714	-0.002	<i>ns</i>	.116	.065	<i>ns</i>
Asian	.083	13.35	2.71	-0.010	<i>ns</i>	<i>ns</i>	<i>ns</i>	.740
Science								
White	.038	9.62	1.88	0.000	<i>ns</i>	.164	<i>ns</i>	.473
African American	.068	.472	.043	0.138	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
Hispanic	.074	1.395	.350	0.102	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>
Asian	.075	11.52	1.04	0.300	<i>ns</i>	<i>ns</i>	<i>ns</i>	<i>ns</i>

NOTE: RMSEA = root mean square error of approximation; *ns* = not significant.

Figure 2
Science Advanced Placement Testing Participation Trends by Ethnicity

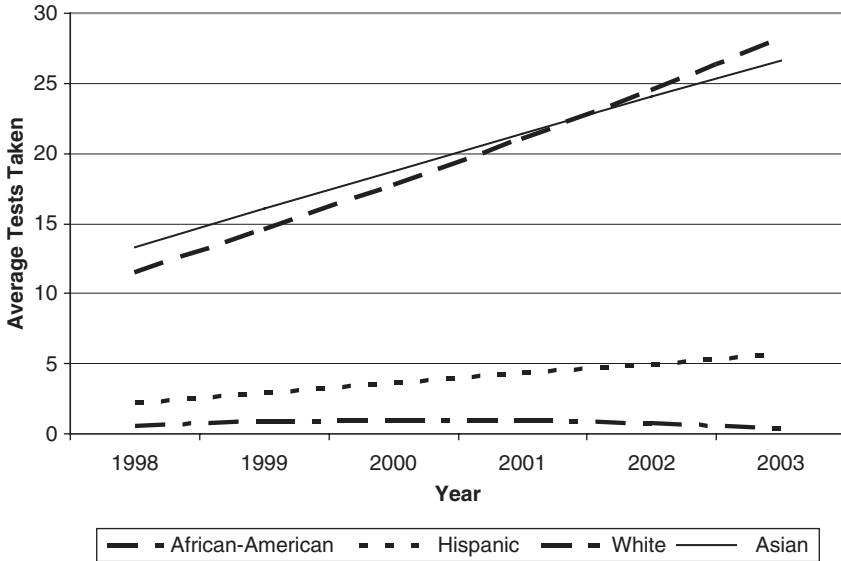


subgroup started out taking fewer tests and grew more slowly over time; and (c) Hispanics, on average, only narrowly surpassed African Americans in their intercept and slope values in mathematics and science.

The data indicate that although African American and Hispanic slopes are positive, the rate of growth is not equal to or comparable with that of Whites and Asian Americans. In addition, Hispanic and African American growth trends appear similar. For these two groups to draw nearer to the participation levels of White and Asian students in a reasonable amount of time, their slope values would have to significantly exceed that of the other subgroups. However, the data show a large inequality in this area. Whites and Asian Americans demonstrate higher intercept values in mathematics and science compared with African Americans and Hispanics. These initial inequalities are compounded as both African Americans and Hispanics have lower slope values over the next 5 years. In short, the slope values show that these growth rate inequalities are not being reduced; in fact, they are increasing over time. For the initial disparity to be reduced, the slope values for the subgroups that suffer the inequality must be greater than those of the advantaged groups.

Results from the models show that as a whole, the covariates exerted varied effects on student growth rates in mathematics and science across the student groups. Adult-student ratio had the most consistent effect on the growth parameters, indicating

Figure 3
Math Advanced Placement Testing Participation Trends by Ethnicity



that for White, Hispanic, and African American students, schools with higher adult–student ratios had greater increases in student test taking in math. For White students, the influence of the adult–student ratio was also found in science. Moreover, although not showing a statistically significant effect for Hispanic and African American students, the covariate student test scores strongly affected White and Asian students in both math and science. This finding suggests that schools with stronger student achievement increased student test taking at a faster rate. Furthermore, academic momentum was positively related to the growth parameter estimate for Hispanics in mathematics participation but not in science. This measure was negatively related to the growth estimates for Whites and Asians in math but unrelated to their estimates for growth in science. Academic momentum was not related to the growth parameter for African Americans in either math or science. Teacher quality had no significant influence on the rate of increase in AP test participation for any of the eight models.

Performance

In addition to participation, this study also explored the extent to which performance on AP tests in mathematics and science improved or lessened for each of these subgroups and sought to identify whether specific features of schools influenced

changes in student performance. Rather than the number of students in each group taking a given AP test, the outcome measure modeled for these analyses is the proportion of students passing the AP tests of interest with a grade of 3 or better. Although the models are similar, the outcome measures are distinctly different from the earlier analysis. As with the earlier analysis, a total of eight models was analyzed to address this question. Parameter estimates and measures of model fit for each model are summarized in Table 2.

Model fit for the linear models with the performance outcomes was much better than the model fit for the linear model for participation outcomes, thus, no quadratic terms were added. All eight models indicate very good model fit (RMSEAs < .05). Significant effects for the covariates are presented in the summary table and will be discussed in the following sections.

Hispanic students outperformed all other subgroups in the rate of change in the percentage of students scoring 3 or better on AP tests in mathematics. Only White students narrowly outpaced Hispanic students in the rate of change in the percentage of students passing AP exams in science. Although Asian Americans had strong initial values, their growth values were less than Whites, African Americans, and Hispanics in mathematics and science performance. The data also suggest that the performance gap will continue to exist for African American and Hispanic students in mathematics and science. Although the percentages of African American and Hispanic students passing the AP exams are increasing, they are not increasing fast enough to realize an equitable standing relative to Whites and Asian Americans in the near future. See Figures 4 and 5 for graphical depictions of these trends in science and math, respectively.

The results from the performance model show that the teacher quality and academic momentum covariates had little or no effect on most of the student groups in both mathematics and science. These covariates displayed only slight significance on African American and Asian American students in the field of mathematics and no significance in science. Student test scores had the most consistent effect on the growth parameters for all subgroups in mathematics and science, suggesting that schools with better student achievement increased student test taking at a faster rate. In addition, the covariate adult–student ratio affected only Hispanic and African American student growth parameters, indicating that for these groups, schools with higher adult–student ratios had greater increases in student test taking in both mathematics and science. White and Asian American students were not significantly affected by this covariate.

Implications and Conclusions

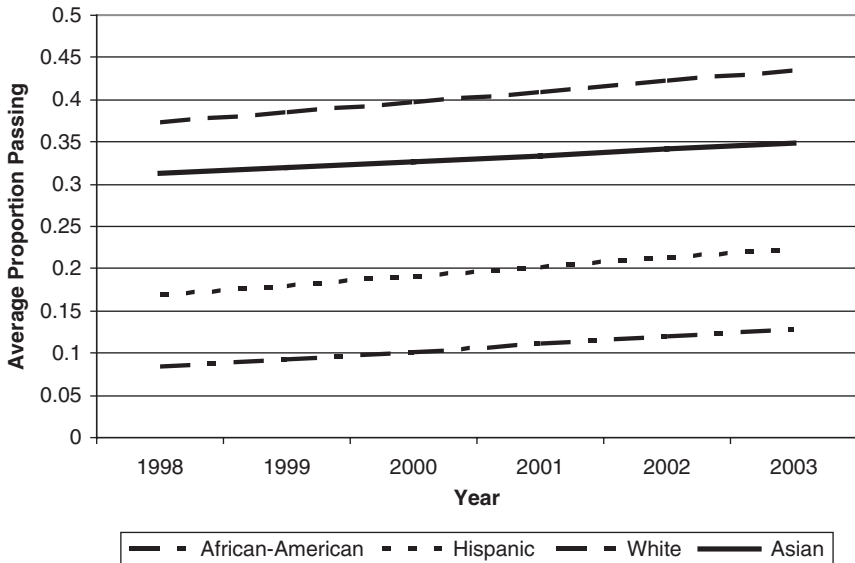
In terms of ethnic participation, the findings show that White and Asian American students have initial mathematics and science values that distinctly separate them from African American and Hispanic students. What is notable about these data is

Table 2
Ethnic Subgroup Performance in Mathematics and Science

Subgroup	RMSEA	Intercept	Slope	Teacher Quality	Adult-Student Ratio	Academic Momentum	Student Test Scores
Math							
White	0.033	0.455	0.014	<i>ns</i>	<i>ns</i>	<i>ns</i>	0.006
African American	0.016	0.107	0.015	<i>ns</i>	0.003	0.001	0.004
Hispanic	0.027	0.229	0.020	<i>ns</i>	0.002	<i>ns</i>	0.005
Asian	0.037	0.390	0.011	<i>ns</i>	<i>ns</i>	0.001	0.003
Science							
White	0.047	0.373	0.012	<i>ns</i>	<i>ns</i>	<i>ns</i>	0.007
African American	0.025	0.083	0.009	<i>ns</i>	0.002	<i>ns</i>	0.005
Hispanic	0.032	0.168	0.011	<i>ns</i>	0.002	<i>ns</i>	0.005
Asian	0.033	0.313	0.007	<i>ns</i>	<i>ns</i>	<i>ns</i>	0.007

NOTE: RMSEA = root mean square error of approximation; *ns* = not significant.

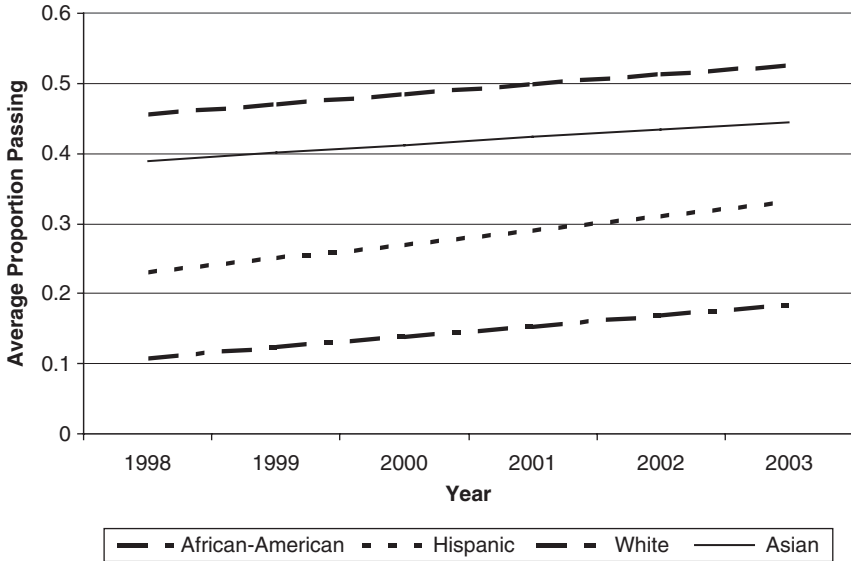
Figure 4
Science Advanced Placement Testing Performance Trends by Ethnicity



just how wide the participation gap is and continues to be between these ethnic subgroups. In both mathematics and science participation, the number of tests taken by White and Asian American students is many times greater than that of Hispanic and African American students. In addition, the data reveal that African American and Hispanic student growth rates are substantially less than those of their ethnic counterparts. The implications of this finding suggest that not only does an ethnic participation gap exist, but it is continuing to expand at a considerable yearly rate, thereby enhancing the college preparatory advantage that some groups of children have over others.

In both mathematics and science, the initial number of tests taken by African American and Hispanic students is remarkably lower than the number for White and Asian American students. Furthermore, the rate of growth for African American and Hispanic students is not remotely equivalent to that of Whites and Asian Americans. These data suggest that African American and Hispanic students will continue to be left behind in AP test taking in mathematics and science. This finding suggests that as fewer numbers of African American and Hispanic students participate in AP test taking, they will also be less competitive in the college admissions process. Furthermore, this lack of equivalent participation will likely lead to African American and Hispanic students being less prepared for college level work in mathematics and science.

Figure 5
Math Advanced Placement Testing Performance Trends by Ethnicity



The mathematics and science performance findings for African American and Hispanic students demonstrate that these subgroups have lower initial values when compared with White and Asian American students. These subgroups demonstrated stronger growth values in mathematics and equivalent or greater growth values in science performance than their White and Asian American counterparts. When the performance data are contrasted with the participation data, African American and Hispanic students show that they are improving at a faster pace than White and Asian American students. Yet, despite these performance gains, the performance gap is still enormous. At the current rate, it would take more than 20 years for African American and Hispanic students to catch up to White and Asian American students. It is recommended that we incorporate college preparedness measures such as AP course taking by ethnicity into statewide accountability systems to enhance schools' attention to these disparities and hold them accountable for reducing these gaps.

One implication from these findings is that traditionally underrepresented students will be less likely to compete and gain entrance to colleges and universities. Furthermore, these students' performance data suggest that when they are accepted to institutions of higher learning, they are less likely to be ready for the academic workload they

encounter. These findings indicate that as smaller numbers of minority students enter college and select mathematics and science majors, fewer of these students will leave with careers in mathematics and science. This state of affairs often leads to decreased social mobility and increased levels of economic disparity for these subgroups.

This study concludes that social inequality in education has, in fact, been increased for African American and Hispanic students in California's school systems. From an examination of the data, African American and Hispanic students initially took fewer AP tests in mathematics and science and their rate of increase in AP testing severely trails behind their White and Asian American counterparts. It is reasonable to conclude from these data that although some positive trends are evident in terms of AP test participation, educational disparities and the inequitable preparation for careers in math and science for students of color persist.

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Richard S. Brown, Ph.D., is an Assistant Professor at the Rossier School of Education at the University of Southern California. His research interests include educational measurement and assessment and educational policy. **D. Michael Campbell, Ed.D.**, is a practicing clinical psychologist and Adjunct Clinical Professor at the Rossier School of Education at the University of Southern California. His research interests deal with understanding and interpreting the inferences derived from educational and psychological learning processes.