Trends in Advanced Placement Science and Mathematics Test-Taking Among Female Students in California: A Latent Variable Approach

D. Michael Campbell, Ed.D.
Rossier School of Education
University of Southern California

Richard Brown, Ph.D.
Rossier School of Education
University of Southern California

Elizabeth Perry, M.A.
University of San Diego

Abstract

This study compares trends in participation and performance on all science and mathematics Advanced Placement exams for female and male students in California high schools over a six-year period. Results indicate that while more females are participating in Advanced Placement science and mathematics they are not performing to the levels of their male counterparts. This performance gap presents a real obstacle for females as they prepare to enter college and later compete for jobs in these fields after graduation. As such, these findings signal the need for additional research that identifies means of reducing the performance gap between males and females in Advanced Placement examinations.

Correspondence should be addressed to D. Michael Campbell, Ed.D., 2041 Paseo Dorado #8, La Jolla, Ca 92037, 619-368-5736, cmik731@hotmail.com

Introduction

More than 25 years ago the debate was waged over whether female students were as capable as male students in the subjects of mathematics and science. In the early 1980s, Benbow and Stanley (1980) suggested that there could be a genetic basis for male superiority in mathematics and that females would be better off accepting this differentiation (as cited in Kolata, 1980). Since this time, numerous studies have aimed to address this issue with the purpose of debunking or supporting the work by Benbow and Stanley. More recently, in a 2005 economic conference, Harvard University President Lawrence Summers offered his personal insights on the issue. He remarked that one determining reason for decreased female performance in mathematics and science had to do with "innate ability" in these academic fields. From Summers' response, a national debate once again erupted over whether intrinsic differences between the sexes were responsible for the underrepresentation of women in mathematics and science.

The renewed debate heighted contemporary scholars' attention to female participation in mathematics and science. One notable national event occurred when the

American Psychological Association held a 2007 forum entitled *Women in Science: Are They Being Held Back*? Contemporary research has added further attention to this topic with the outlook that motivation (Dumais, 2009; Moody & Linn, 1986; Turner & Harriet, 2003), locus of control (Reis & Park, 2001), testing items (Beller & Gafni, 2000; Walsh, Hickey & Duffy,1999), classroom behaviors (Born, Revelle & Pinto, 2002; Inzlincht & Ben-Zeev, 2002), departmental and institutional factors (Cohoon, 2001), teacher-student interactions (Duffy, Warren & Walsh, 2001; Potvin, Hazari, Tai & Sadler, 2009), teacher preparation (Fraser-Abder, 2001), and self-efficacy (Britner, 2008; Ferla, Valcke & Cai, 2009; Gainor, 1998; Halpern, Benbow, Geary, Gur, Hyde & Gernsbache, 2007b; Herbert & Stipek, 2005; Huebner, 2009; Nauta, Epperson & Kahn, 1998; Pearl, Pollack, Riskin, Thomas, Teshome, Maushak, & Athreya, 2001; Wolf & Wu, 1990) may be useful determinants in leveling the "cognitive field" in these subject areas. While some studies have focused on the biological-based differences and others on learning and socialization issues, neither the biological nor the environmental rationale has produced unequivocal evidence to support the involvement disparities by females (Oakes, 1990). In essence, the competing sides of the literature have yet been able to undeniably prove their positions on why female achievement tends to trail male achievement in mathematics and science.

Decades of research in cognition have largely drawn attention to the fact that female students have seldom participated in mathematics and science in the same numbers as their male counterparts. Most of the contemporary literature is no longer focused on whether female students are as intelligent as their male counterparts; instead, the focus involves examining the motives behind why large numbers of young girls avoid intermediate and advanced mathematics and science curriculum and subsequent careers in associated fields. Numerous difficulties have been illustrated in the literature including teacher intimidation and lack of proper advising (Brainard, Laurich-McIntyre & Carline, 1995; Cooney & Bottoms, 2003), chilly academic climates with messages that reinforce sexists expectations (Ginorio, 1995; Guiso, Monte, Sapineza, & Zingales, 2008), poor mentoring and student relationships with faculty (Herzig, 2004), less student interest and confidence (Catsambis, 1994), dearth of adequate feedback (Halpern, Aronson, Reimer, Simpkins, Star & Wentzel, 2007a; Huebner, 2009), and the deficit of (Nobles & McDonald, 1996) and importance of female role models (Halpern, Aronson, Reimer, Simpkins, Star, & Wentzel, 2007; Huebner, 2009; Karnes & Stevens, 2002). Teacher stereotypes have also been linked to poor female mathematics and science participation. These stereotypes include teacher and textbook sole reliance on prominent male figures in math and science. As Nobles and McDonald (1996) remark, rarely, if ever, were female mathematicians and scientists highlighted as major contributors to these fields. As a consequence, the disparity in mathematics and science participation and upper-level course taking contributes to the large "gap" in the number of females choosing professions in math, science, and technology fields (Campbell, 1992; Johnson, 2000). Furthermore, Dick and Rallis (1991) remarked that even when high school females are performing at higher academic levels than their male counterparts, they continue to express less interest in participating in mathematics and science careers. One theory proposed by Taylor, Friot & Swetnam, (1997) suggests that female choices to pursue mathematics and science education are reinforced daily by individual experiences in and out of the classroom. Many times, female students feel that there is a societal expectation that mathematics and science are "male domains." Given this, Campbell, Jolly, Hoey &

Perlman, (2002) observed that female students are much less apt than male students to continue in career fields in quantitative disciplines. Similarly, Kerr and Robinson-Kurpius (2004) highlight that many Hispanic female students are expected to stay close to home, support family objectives, and adhere to cultural ideals. In the same way, African American young women often lack the social support and educational self-efficacy necessary to persist in math and science majors (Oakes, 1990).

While the literature offers a wide range of reasons why female participation is below that of their male counterparts the notion of stereotype threat has taken new importance in many academic circles. Stereotype threat is a feeling that individuals experience when they are in jeopardy of confirming a negative stereotype in the eyes of others (Spencer, 1997). Research has shown that female students are exceedingly aware that gender stereotypes depict them as being bad at math and science (Bell & Spencer, 2002; Huguet & Régner, 2009; Keller, 2002; Kiefer & Sekaquaptewa, 2007; Marx, Brown & Steele, 1999; Nosek, Smyth, Sriram, Lindner, Devos, Ayala, Bar-Anan, Bergh, Cai, Gonsalkorale, Kesebir, Maliszewski, Neto, Olli, Park, Schnabel, Shiomura, Tulbure, Wiers, Somogyi, Akrami, Ekehammar, Vianello, Banaji, & Greenwald, 2009; Shih, Pittinsky, & Ambady, 2002; Smith, Sansone, & White, 2007; Smith & White, 2002; Steele, 1999; Thoman, White, Yamawaki, & Koishi, 2008; Verity et. al, 2002). As a result, many of these students reason that poor outcomes on mathematics or science tests are directly linked to their gender (Steele, James, & Barnett, 2002). This thinking, in turn, may create anxiety and/or strong performance attributions that may lead to the originally imagined outcomes. To avoid these negative stereotypes, female students may leave mathematics and science courses for more traditionally female options in other fields such as education and the social sciences (Jacobs, 2005).

Fortunately, the contemporary literature has shown that when teachers, especially in middle and high school grades, make math and science classrooms free from stereotype threat (Brownlow, Jacobi & Rogers, 2004), encourage a safe and nurturing environment (Allen, 1995; Gavin, 2000), and remove obstacles that hinder student self-efficacy (Betz & Hackett, 1983; Huang & Brainard, 2001; Kerr & Robinson-Kurpius, 2004; Ziegler & Heller, 2000), female students become more effectively prepared to enter and participate in advanced courses in these fields. Furthermore, parental and mentoring influences have also been shown to positively influence female student preparation and ensuing participation in mathematics and science. Gavin (2000) found that nurturing and encouraging math and science ability through at-home problem solving activities, gender equal career expectations, and exposure to female role models in math and science was a strong foundation of later scholastic ability and reduction of stereotype threat. Moreover, the literature is rich with studies linking nurturing parental (Beckwith, 1983; Ferry, Fouad & Smith, 2000; Gavin, 2000) and mentoring activities (Herzig, 2004; Karnes & Stevens, 2002; Kerr & Robinson-Kurpius, 2004; McLaughlin, 2005; Murphy & Sullivan, 1997) to increased female preparation and stereotype threat reduction in mathematics and science. Whatever the explanation, it is important to identify if the patterns observed in female participation and performance in advanced science and mathematics are persisting, or to what extent they are changing over time.

Objective: Measurement and Assessment of Student Participation and Performance

This study is designed to address two main objectives. The first objective is to compare the extent to which opportunities to take mathematics and science Advanced Placement exams are increasing or decreasing for female students by examining six years of student testing data and to identify features of high schools that relate to greater expansion in Advanced Placement test taking for females in these areas. The second objective is to compare changes in performance on Advanced Placement tests in mathematics and science between male and females students and to identify what features of schools influence these changes in student performance.

Methodology

Whenever we are 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 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 Advanced Placement test taking and performance. However, in some instances it may be necessary to amend the linear model to include a non-linear component to improve the explanatory capability of the model and improve the model fit to the observed data. In only one case (female mathematics participation) was it necessary to get the model fit below the specified threshold.

The starting point for change over a given time period is referred to as the *intercept (i)***.** The *intercept (i)* is the beginning value of our data set in year 1; identified in Figure I as indicator t_1. Indicators t_1 through t_6 depict the data set years ranging from 1998 to 2003. In addition to the *intercept (i)*, the *linear slope* describes the amount of change for each measured variable. In short, this parameter illustrates how much the curve grows each year (Acock & Fuzhong, 1999). Other variables, called covariates, which are depicted by the indicators $\mathbf{C}_1$ through $\mathbf{C}_4$, may impact the rate of change and consequently give insights into what conditions at the school might relate to varying levels of change.

The school level covariates used in this study include such features as teacher quality, the adult/student ratio, a school's academic momentum, and student achievement level. 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 teachers and certificated 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.

In addition, the relationship between the *intercept (i)*, and the *slope* is estimated in this latent variable growth model, 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 Advanced Placement testing in the initial year. Negative values reflect slower growth rates for schools with higher levels of student test taking in 1998.

Listed below is a general representation of the Latent Variable Growth Model for males and females in mathematics and science.

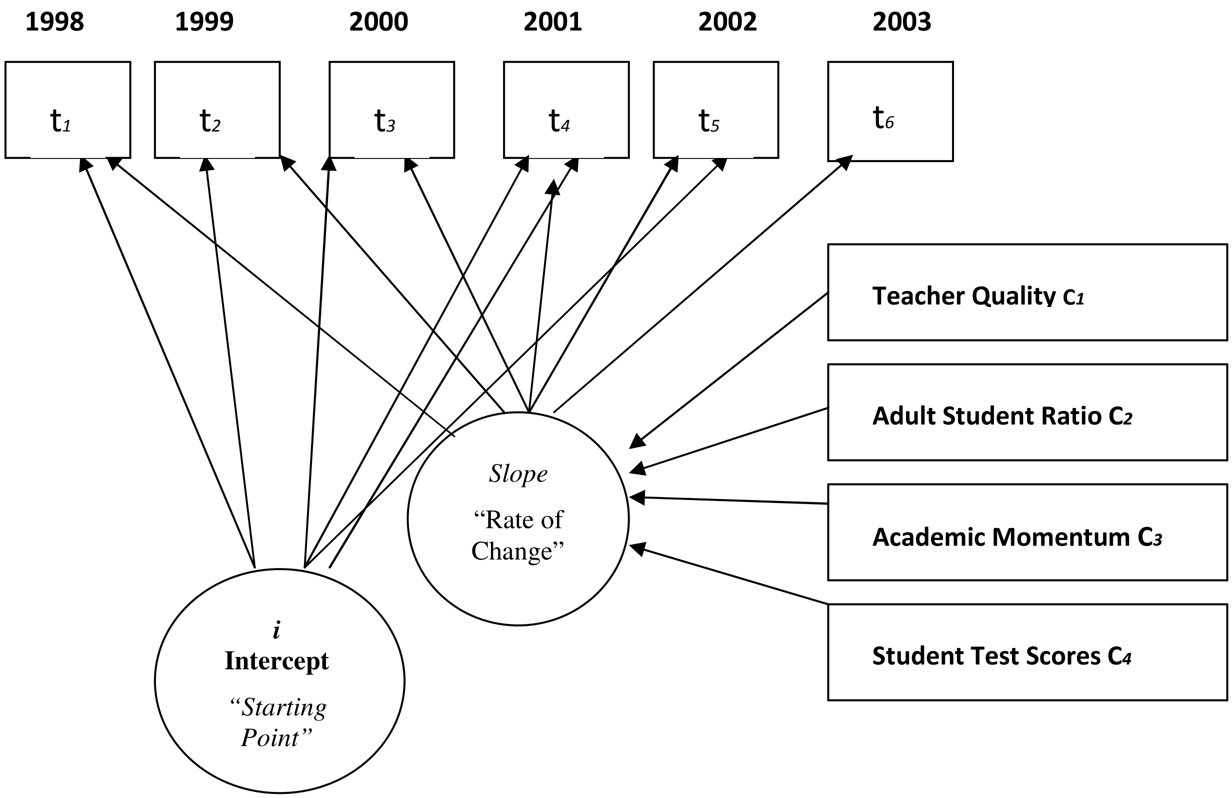

Figure I. General Latent Variable Growth Model

Data Set

The Advanced Placement testing data used in this study include information for all Advanced Placement tests taken by California high school students from 1998 to 2003. In the academic field of science the tests included Biology, Chemistry, Macroeconomics, Microeconomics, Environmental Science, Physics B, and Physics C. In the field of mathematics the tests included Calculus AB, Calculus BC, Statistics Computer Science A, and Computer Science AB. The data were disaggregated by subject area, ethnicity, and school site for all 6 years. Next, the data were disaggregated by gender. The starting data set included 16,383 records from 874 high schools in 12 Advanced Placement subjects.

Results

Model Fit

Before interpreting the estimates derived from the proposed models, it is important to identify 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 for the data. Hu and Bentler (1999) propose .06 as an optimal critical value for indicating close fit. Browne and Cudeck (1993) suggest values ranging from .06 to .08 indicate acceptable fit, and values ranging from .08 to .10 indicate mediocre fit. RSMEA values above .10 would reflect a poor fitting model. While the linear models using the performance data all indicated very good fit, one linear model (female math participation) using the participation data as outcomes generated a fit statistic beyond the acceptable thresholds. In order to address this and provide a better model fit to the data, a quadratic growth term was added to the model. This allows the growth trajectories to be non-linear, or level off or accelerate over time. This addition resulted in better explanatory power for the model and fit statistic within the acceptable limits.

Participation

The first research question investigated is principally interested in the rate of male and female participation. In order to measure participation, we must focus on the slope segment of this research model. Each slope value illustrates whether the opportunities in mathematics and science Advanced Placement testing are increasing or decreasing for the males and female students examined in this study. The higher the slope value for each group, the faster this group's participation in Advanced Placement mathematics and science is growing. The lower the slope values, the slower each group is increasing participation in Advanced Placement mathematics and science testing. When the slope values are compared in relation to each group, meaningful testing trends can be determined. The growth data that addresses this research question are located in the third column labeled "Slope" in Table I.

Table I
Gender Participation in Mathematics and Science

Subgroup	RMSEA	Intercept	Slope	Teacher Quality	Adult/Student Ratio	Academic Momentum	Student Test Scores
Female Science Participation	0.065	14.40	2.23	NS	0.235	NS	0.379
Male Science Participation	0.065	12.15	2.55	NS	0.196	0.022	0.301
Female Math Participation*	0.084	17.98	3.32	NS	0.252	-.123	0.866
Male Math Participation	0.061	14.48	3.15	NS	0.208	NS	0.500

*included a non-linear term to enhance model fit. The slope reflects the linear slope and the average effect of the non-linear term.

In the discipline of mathematics, males had an intercept of 14.48 and a slope of 3.13. This means that across the full population of high schools in California, the average number of Advanced Placement tests taken by males in mathematics in 1998 was slightly over 14. This group's test participation in math grew at a rate of 3.13 new tests each year or, on average, 3.13 new tests were taken by males each year at each high school. As compared to males, females had a larger intercept value of 17.98 and a slope of 3.32. While the initial value of females was noticeably larger than males, the growth rates are largely comparable. The data showed that gender played a role in the area of mathematics participation as females display higher intercept values (17.98) as compared to their male counterparts (14.48). Additionally, females (3.32) slightly outpaced males (3.13) in mathematics participation growth rates. If these trends continue the data indicate that on average, and across all California high schools, the number of tests taken by females will continue to outpace the number of tests taken by males in mathematics.

In the academic discipline of science, males had an intercept of 12.14 and a slope of 2.55 in participation. This means that across the full population of high schools in California, the average number of Advanced Placement tests taken by males in science in 1998 was slightly over 12. In comparison, females had an intercept of 14.40 and a slope of 2.23. Gender discrepancy was once again noticeable as females, in the area of science participation, displayed higher intercept values (14.40) when compared to their male counterparts (12.15). However, in contrast to mathematics participation, males slightly outpaced female growth rates in science participation. The slope values for both genders (2.55 and 2.23 respectively) in science, as they were in mathematics, are to a large extent similar. See Figure II for a graphical display of the trends in math and science AP testing participation by gender.

The next step in analyzing the data in mathematics and science participation involves investigating the individual covariate effects on the data set. From the examination of the covariate data, the features of high schools that relate to greater expansion in Advanced Placement testing in mathematics and science vary between the genders. In terms of mathematics participation, teacher quality and academic momentum did not have much significance, while adult/student ratio and student test scores were significant for both males and females. This means that the percentage of fully credentialed teachers and a school's improvement in proficiency rates on state assessment tests did not lead to increases in Advanced Placement test taking by males or females. In science participation once again this study found that teacher quality had no significant impact on either group; however, adult/student ratio was shown to relate positively to an expansion in Advanced Placement test taking in science for both males and females. That is, the ratio of adults in the school to students related to positive changes in Advanced Placement science test taking for both males and females. Additionally, academic momentum lead to increased Advanced Placement test taking by males for science only, but had no significant impact on females in science and a negative impact in mathematics.

Performance

In addition to participation, this study also explored the extent to which performance on Advanced Placement tests in mathematics and science improved or lessened for each gender and sought to identify whether specific features of schools influenced student performance. Rather than the number of students in each group taking a given Advanced Placement test, the outcome measure modeled for these analyses is the proportion of students passing the Advanced Placement 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. Parameter estimates and measures of model fit for each model are summarized in Table II.

Table II
Gender Performance in Mathematics and Science

Subgroup	RMSEA	Intercept	Slope	Teacher Quality	Adult/Student Ratio	Academic Momentum	Student Test Scores
Female Science Performance	0.039	0.316	0.007	NS	NS	NS	0.008
Male Science Performance	0.035	0.401	0.008	NS	NS	NS	0.009
Female Math Performance	0.048	0.410	0.009	NS	NS	NS	0.008
Male Math Performance	0.051	0.486	0.011	NS	NS	NS	0.005

In the academic discipline of mathematics, males and females had intercepts values of .486 and .410 respectively. This means that the percentage of male and female students scoring “3” or better, on average, across all California high schools, was 48.6% for males and 41.0% for females. The slopes for males and females were relatively similar with values at .011 and .009 respectively. A data value of .011 indicates that the percentage of male students passing Advanced Placement tests increased by a value of 1.1 each year. Likewise the percentage of female students scoring “3” or better grew by a value of .9 each year. The data suggest that gender groups differed in the area of mathematics performance as males (.486, .011) displayed higher intercept and slope values as compared to their female (.41, .009) counterparts.

In the academic discipline of science, males (.401) had higher intercept values in science performance as compared to females (.316). This means that across the full population of high schools in California, on average, the percentage of male and female students scoring “3” or better on Advanced Placement tests was 40.1% and 31.6% respectively. The male student slope value of .008 indicates that for every year, the average increase in the percentage of male students scoring “3” or better was .8%. In contrast to males, females had a slope of .007; meaning that, on average, an additional .7% of female students scored “3” or better in Advanced Placement test taking per year. While these data are not that widely divergent, it is worth noting that in both mathematics and science performance, males began with higher passing relates and continue to outpace females in performance rates throughout the data years 1998 to 2003. The data indicate that the performance gap between males and females is not reducing. See Figure III for a graphical display of the trends in math and science AP testing performance by gender.

In terms of the covariate data, teacher quality was not shown to positively relate to the increases in the percentage of males or females passing Advanced Placement examinations in mathematics and science. This finding suggest that teacher quality in California high schools had no positive affect on the percentage of males or females passing Advanced Placement examinations in these disciplines. Similarly, the variables adult/student ratio and academic momentum failed to show a positive relationship to increased percentages of males and females scoring “3” or better on Advanced Placement examinations in math and science. Only academic achievement at the schools, as measured by performance on state examinations, was positively related to an increased percentage in both genders passing Advanced Placement tests in mathematics and science. This suggests that greater increases in passing rates for males and females occur in high schools with better academic achievement.

Study Implications

The prominent gender distinctions are centered on the fact that females took more tests in both mathematics and science compared to their male counterparts. These findings are significant because they show that females are, in fact, actively involved in mathematics and science Advanced Placement test taking. The data suggest that females are participating at comparable rates in mathematics and science Advanced Placement testing and are continuing to make substantial strides in this area. The data also indicates that the growth rates for each gender were affected by certain features in California high schools that relate to greater expansion in Advanced Placement test taking in mathematics and science. These features include adult/student ratio, a school's academic momentum, and student test scores on state examinations.

In the field of mathematics, the findings show that the adult/student ratio and student test scores largely influenced the growth rates for both male and female students. However, neither male nor female growth rates were influenced by teacher quality or a high school's academic momentum. The data findings are important because they show that greater expansion in Advanced Placement testing will occur for males and females in high schools with positive adult/student ratios and strong academic achievement.

In mathematics and science participation, the data demonstrated that females had higher initial participation rates as compared to their male counterparts. Females also grew at higher or comparable rates in mathematics and science over the years. These findings show that in terms of Advanced Placement test taking, females are matching or outpacing males in the areas of mathematics and science. The data suggest that females, in fact, are actively participating in Advanced Placement test taking in mathematics and science.

Males had higher intercept and slope values in both mathematics and science performance data. This means that males, as compared to females, have higher initial passing scores in Advanced Placement test taking in mathematics and science. Furthermore, males demonstrate marginally stronger yearly performance growth rates in mathematics and science Advanced Placement test taking. When these data are contrasted with the data in gender participation, it illustrates that although more females are participating in Advanced Placement mathematics and science test taking their passing rates are still lower than that of males. Although female participation rates in mathematics and science are encouraging, the implications for this group's performance data are problematic. While more females are participating in Advanced Placement mathematics and science, they are not performing at the levels of their male counterparts. This performance gap presents a real obstacle for females as they prepare to enter college and later compete for jobs in these fields after graduation. Furthermore, the gap is not diminishing. Ergo, the problem self-perpetuates as reduced numbers of females in mathematics and science lead to fewer successful examples of mentors for aspiring female students. Ultimately, the findings suggest that continued underrepresentation in the number of females with mathematics and science majors in colleges and universities will lead to decreased participation of females in the domestic workforce. This reduction in the workforce may lead to a continued lack of economic and social power for this group.

Conclusions

Understanding participation and performance in Advanced Placement mathematics and science is exceedingly important for California's future. As greater numbers of females are making up the populations of California's elementary, middle, and high schools, adequate and equitable mathematics and science preparation for these students is essential. This research identifies patterns of participation and performance of female high school students in California on Advanced Placement mathematics and science examinations over a five-year period of time. Rates of participation in Advanced Placement testing indicate that female students are participating nearly on par with their male counterparts and even at greater rates in mathematics; however, the identified lower performance of females on Advanced Placement examinations is a cause for concern.

While this study reveals that academic achievement, as measured by test scores on state examinations, correlates with greater performance on Advanced Placement examinations, more research is needed to examine why female students are not performing as well as male students. As gender equity in participation increases, what explains the disparity in performance levels? Are instructional strategies unequal or insufficient, leading to lower performance by females? Or, for example, are Advanced Placement tests an inaccurate or inequitable assessment of skill, due to implicit stereotyping or other gender bias? There is likely to be more than one factor at play. Identifying why female students in California underperform on Advanced Placement testing in mathematics and science in relation to male students is imperative for increasing female involvement in these fields in higher education and related professions. What message do low-test scores send to females about ability – and in turn, how does this influence the decisions of female students to pursue academic degrees and professions in the fields of mathematics and science.

Once the causes of underperformance are determined, further research is needed to identify the means for reduce this disparity. A recent study by Halpern et al. (2007) identifies five strategies to encourage females in mathematics in science, including: teaching females students that success in mathematics and science is not based on innate ability, increasing exposure of female students to successful female mathematicians and scientists, providing “prescriptive, informational feedback,” creating classroom environments that engage and create lasting interest in science and math, and providing additional training for female students in spatial skills (p. 6). Identifying why female students are underperforming in relation to their male classmates will aid in identifying if Halpern et al.’s suggested strategies suffice, or if additional or modified strategies are needed to address test performance specifically.

There are a multitude of reasons why Advanced Placement test taking should be equitable for all students. The two important reasons include the competitive nature of college admissions for in-state colleges and universities and the fact that students are able to decrease the cost of college attendance by earning college credit for these courses. Another important reason is that there have been decades of inadequate preparation that have created a widening deficit of qualified workers in the global workplace. In essence, as fewer numbers of qualified females focusing on mathematics and science enter the educational pipeline, fewer students from this group believe careers in mathematics and sciences are obtainable. This process leads to a lack of creative ingenuity and decreased domestic competitiveness in the global industrial workplace.

A substantial portion of the current literature on mathematics and science preparation (Brainard, Laurich-McIntyre, & Carline, 1995; Brown, 2004; Furry and

Beasley, 1999; Furry and Hecsh, 2001; Johnson, 2000; Oakes, 1990; Solorzano & Ornelas, 2002; Stanley, 1997; Rinne, 2000, and Ratliff, 2001) discusses the declining trends of female participation in mathematics and science and how these trends could lead to insufficient representation in industry and educational leadership positions. However, few studies have looked beyond female participation in advanced mathematics and science testing to examine the performance rates of these students. While it is important to inspect the number of tests taken by gender, it is also essential to examine the percentage of students passing Advanced Placement tests in mathematics and science and their rates of change over time. The significance of this study rests in the fact that it highlights the growth of both genders, what school features impact growth rates, and then observes exactly where the discrepancies are occurring.

References

Acock, A. C., & Fuzhong, L. (1999, October). *Latent Growth Curve Analysis: A Gentle Introduction.* Paper presented at the Oregon State University Department of Human Development and Family Sciences conference, Corvallis, OR.

Allen, D. (1995). Encouraging success in female students: Helping girls develop math and science skills. *Gifted Child Today, 18*(20), 4-45.

Beckwith, J. (1983). Gender and math performance: Does biology have implications for educational policy*? Journal of Education, 165*(2), 158-174.

Benbow, C. P. & Stanley, J. C. (1980). Consequences in high school and college of sex differences in mathematical reasoning ability: A longitudinal perspective. *American Education Research Journal, 19*(4), 598-622.

Bell, A.E., & Spencer, S. J. (2002). The effect of stereotype threat on women's performance on the fundamentals of engineering exam. Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition. Retrieved December 18, 2007 from http://www.ecpe.vt.edu/fac_support/DSPCL/docs/ASEE02.pdf

Beller, M. & Gafni, N. (2000). Can item format account for gender differences in mathematics achievement? *Sex Roles, 42*(2), 1-21.

Betz, N. E. & Hackett, G. (1983). The relationship of mathematics self-efficacy expectations to the selection of science-based college majors. *Journal of Vocational Behavior, 23*(3), 329-345.

Born, W. K., Revelle, W., & Pinto, L. H. (2002). Improving biology performance with workshop groups. *Journal of Science Education and Technology, 11*(4), 347-365.

Brainard, S. G., Laurich-McIntyre, S., & Carline, L., (1995). Retaining female undergraduate students in engineering and science. J*ournal of Women and Minorities in Science and Engineering, 2*(4), 255-267.

Britner, S. L. (2008). Motivation in high school science teachers: A comparison of gender differences in life, physical, and earth science classes. *Journal of Research in Science Teaching*, *45*(8), 955-970.

Brown, R. (2004). Changes in Advanced Placement Test taking in California 1998-2003. (Draft deliverable to UC All Campus Consortium On Research for Diversity). Los Angeles, CA: University of California, UC ACCORD).

Browne, M.W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K.A. Bollen & J.S. Long (Eds.), *Testing structural equation models* (pp. 136-162). Newbury Park, CA: Sage.

Brownlow, S., Jacobi, T., & Rogers, M. I. (2004). Science anxiety as a function of gender and experience. *Sex Roles*, *42(1-2)*, 1573-2762.

Campbell, P. B. (1992). *Nothing can stop us now: Designing effective programs for girls in math, science, and engineering*. New York, NY: Women's Educational Equity Act Publishing Center.

Campbell, P. B., Jolly, E., Hoey, L., & Perlman, L. K. (2002). *Upping the numbers: Using research-based decision making to increase diversity in the quantitative disciplines* (College Rep. No. 02-02). Princeton, NJ: GE Foundation.

Catsambis, S. (1994). The path to math: Gender and racial-ethnic differences in mathematic participation from middle school to high school. *Sociology of Education*, 67(1), 199-215.

Cohoon, J. M. (2001). What causes women to discontinue pursuing the undergraduate computer science major at higher rates than men: Toward improving female retention in the computer science major. *Communications of the ACM 44(*5) 108-114.

Conney, S., & Bottoms, G. (2003). *Middle grades to high school: Mending a weak link* (Report No. EA-032-691). Atlanta, GA: Southern Regional Education Board. (ERIC Reproduction Service N. ED479785)

Dick, T. P., & Rallis, S. F. (1991). Factors and influences on high school student's career choices. *Journal of Research in Mathematics Education, 22*(4), 281-292.

Duffy, J., Warren, K., & Walsh, M. (2001). Classroom interactions: Gender of teacher, gender of student, and classroom subject. *Sex Roles, 45*(9/10), 579-593.

Dumais, S. A. (2009). The academic attitudes of American teenagers, 1990-2002: Cohort and gender effects on math achievement. *Social Science Research*, 38(4), 767-780.

Ferry, T. R., Fouad, N. A., & Smith, P. L. (2000). The role of family context in a social cognitive model for career-related choice behavior: A math and science perspective. *Journal of Vocational Behavior, 57*(1), 348-364.

Ferla, J., Valcke, M., & Cai, Y. (2009). Academic self-efficacy and academic self-concept: Reconsidering structural relationships. *Learning and Individual Differences*, *19*(4), 499-505.

Fraser-Abder, P. (2001). Preparing science teachers for culturally diverse classrooms. *Journal of Teacher Education, 12*(2), 123-131.

Furry, W.S., & Beasley, K. (Eds.) (1999). The Advanced Placement program: California's 1997-98 experience. Sacramento, California: California State University, Sacramento, The CSU Institute for Educational Reform.

Furry, W.S., & Hecsh, J. (Eds.) (2001). *Characteristics and performance of Advanced Placement classes in California*. Sacramento, California: California State University, Sacramento, The CSU Institute for Educational Reform.

Gainor, K. A. (1998). Social cognitive expectations and racial identity attitudes in predicting the math choice intentions of Black college students. *Journal of Counseling Psychology, 45*(4), 403-413.

Gavin, K. M. (2000). *What parents need to know about…encouraging talented girls in mathematics*. Paper presented at the annual meeting for the National Research Center on the Gifted and Talented, New Haven, CT.

Ginorio, A. B. (1995). *Warming the climate for women in academic science*. Washington, DC: Association of American Colleges and Universities.

Guiso, L., Monte, F., Sapienza, P., Zingales, L., (2008). Culture, gender, and math. *Science, 320*(5880), 1164-1165.

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J., & Wentzel, K. (2007a). *Encouraging girls in math and science: IES practice guide* (NCER 2007-2003). Washington, DC: Institute of Educational Sciences, U.S. Department of Education. Retrieved November 4, 2009 from http://ies.ed.gov/ncee/wwc/pdf/practiceguides/20072003.pdf

Halpern, D. F., Benbow C. P., Geary, D. C., Gur, R. C., Hyde, J.S., & Gernsbache, M. A. (2007b). The science of sex differences in science and mathematics. *Psychological Science in the Public Interest*, 8, 1-51.

Haung P. M., & Brainard, S. G. (2001). Identifying determinants of academic self-confidence among science, math, engineering, and technology students. *Journal of Women and Minorities in Science and Engineering, 7*(4), 315-337.

Herbert, J. & Stipek, D. (2005). The emergence of gender differences in children's perceptions of their academic competence. *Applied Developmental Psychology*, 26(3), 276-295.

Herzig, A. H. (2004). Slaughtering this beautiful math: graduate women choosing and leaving mathematics. *Gender and Education, 16*(3), 379-395.

Hu, L., & Bentler, P.M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1-55.

Huebner, T. A. (2009). Encouraging girls to pursue math and science. *Educational Leadership*, *67*(1), 90-91.

Huguet, P. & Régner, I. (2009). Counter-stereotypic beliefs in math do not protect school girls from stereotype threat. *Journal of Experimental Social Psychology*, *45*(4), 1024-1027.

Inzlincht, M. & Ben-Zeev, T. (2002). A threatening intellectual environment: Why females are susceptible to experiencing problem-solving deficits in the presence of males. *Psychological Science, 11*(5), 365-371.

Jacobs, J. E. (2005). *Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned*? New York, NY: Wiley Periodicals.

Johnson, R. M. (2000, March). *Gender differences in mathematics performance: Walberg's educational productivity model and the NELS: 88 Database*. Paper presented at the meeting of the American Educational Research Association, New Orleans, LO.

Karnes, F. A., & Stephens, K. R. (2002). *Young women of achievement: A resource for girls in science, math and technology.* Amherst, NJ: Prometheus Books.

Keller, J. (2002). Blantant stereotype threat and women's math performance: Self-handicapping as a strategic means to cope with obtrusive negative performance expectations. *Sex Roles, 47*(3/4), 1893-198.

Kerr, B., & Robinson-Kurpius, S. E. (2004). Encouraging talented girls in math and science: effects of a guidance intervention. *High Ability Studies, 15*(1), 85-102.

Kiefer, A.K., Sekaquaptewa, D. (2007). Implicit stereotypes, gender identification, and math-related outcomes: A prospective study of female college students. *Psychological Science*, *18*(1), 13-18.

Kolata, G.B. (1980). Math and sex: Are girls born with less ability? *Science, 210*(4), 1234-1235.

Marx, D. M., Brown, J. L., & Steele, C. M. (1999). Allport's legacy and the situational press of stereotypes. *Journal of Social Issues, 55*(3), 491-502.

McLaughlin, R. (2005). Girls in science. *Science Scope, 28*(7), 14-15.

Moody, C. D. & Linn, E. (1986). *Fostering sex equity in math*. Ann Arbor, MI: McGraw-Hill.

Murphy, D. S., & Sullivan, K. (1997). *Connecting adolescent girls of color and math/science interventions*. (Report No. SE-060-479). Baltimore, MD: Association of Supervision and Curriculum Development. (ERIC Document Reproduction Service No. ED410106)

Nauta, M. M., Epperson, D. L., & Kahn, J. H. (1998). A multiple-groups analysis of predictors of higher level career aspirations among women in mathematics, science, and engineering majors. *Journal of Counseling Psychology, 45*(4), 483-496.

Nobles, C. H., & McDonald, S. B. (1996). Equity under the microscope: Forgotten women in math and science. *School Library Journal, 42*(1), 28-31.

Nosek, B. A., Frederick, L. S., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., Bar-Anan, Y., Bergh, R., Cai, H., Gonsalkorale, K., Kesebir, S., Maliszewski, N., Neto, F., Olli, E., Park, J., Schnabel, K., Shiomura, K., Tulbure, B. T., Wiers, R, W., Somogyi, M., Akrami, N., Ekehammar, B., Vianello, M., Banaji, M. R., Greenwald, A. G. (2009). National differences in gender-science stereotypes predict national six differences in science and math achievement. *Proceedings of the National Academy of Science*, *106*(26), 10593-10597.

Oakes, J. (1990). Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science (Report No. NSF-R-3928). Washington, D.C.: National Science Foundation. (ERIC Document Reproduction Services No. RIEJUL1 991)

Pearl, A., Pollack, M. E., Riskin, E., Thomas, B., Wolf, E., & Wu, A. (1990). Becoming a computer scientist: A report by the ACM committee on the status of women in computing science. *Communication of the ACM, 33*(11), 47-57.

Potvin, G., Hazari, Z., Tai, R. H. & Sadler, P. M. (2009). Unraveling bias from student evaluations of their high school science teachers. *Science Education*, 93(5), 827-845.

Ratliff, C. (2001). *Performance indicators of California higher education*. (Report No. HE-034-055). Sacramento, CA: California State Postsecondary Education Commission. (ERIC Document Reproduction Service No. ED453731)

Reis, S. M., & Park, S. (2001). Gender differences in high-achieving students in math and science. *Journal for the Education of the Gifted, 25*(1), 52-73.

Rinne, D. H. (2001*). Advanced Placement exams 1999-2000: Results for WCPSS and EBN districts* (Report No. 01.35). Raleigh, NC: Department of Evaluation and Research. (ERIC Document Reproduction Service No. ED457227)

Shih, M., Pittinsky, T. L., & Ambady, N. (2002). Stereotype susceptibility: Shifts in quantitative performance from socio-cultural identification. *Sex Roles, 34*(1/2), 334-335.

Smith, J. L., Sansone, C., & White, P.H. (2007). The stereotypes task engagement process: The role of interest and achievement motivation. *Journal of Educational Psychology*, *99*(1), 99-114.

Smith, J. L., & White, P. H. (2002). An examination of implicitly activated, explicitly activated, and nullified stereotypes on mathematical performance: It's not just a woman's issue. *Sex Roles, 47*(3/4), 179-191.

Solorzano, D.G., & Ornelas, A. (2002). A critical race analysis of Advanced Placement classes: A case of educational inequalities. *Journal of Latinos and Education, 82*(1), 215-229.

Spencer, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist, 52*(6), 613-629.

Stanley, J.C. (1997, April). *Gender differences, especially on Fifty College Board Achievement Tests.* Paper presented at the Annual Meeting of the Eastern Psychological Association, Washington D.C.

Steele, C. M. (1999). Thin ice: Stereotype threat and Black college students. *The Atlantic Online, 22*(2), 22-34.

Steele, J., James, J. B., & Barnett, R. C. (2002). Learning in a man's world: Examining the perceptions of undergraduate women in male-dominated academic areas. *Psychology of Women Quarterly, 26*(1), 46-50.

Taylor, M. J., Friot, F. E., & Swetnam, L. (1997). *Women who say "yes" when science says "no": their lessons for future students and teachers* (Report No. SP-037-223). Phoenix, AZ: American Association of Colleges for Teacher Education. (ERIC Document Reproduction Service No. ED405340)

Teshome, Y., Maushak, N., & Athreya, K. (2001). Attitude toward informal science and math: A survey of boys and girls participating in hands-on science and math. *Journal of Women and Minorities in Science and Engineering, 7*(1), 59-74.

Thoman, D. B., White, P. H., Yamawaki, N., Koishi, H. (2008). Variations of gender-math stereotype content affect women's vulnerability to stereotype threat. *Sex Roles*, *58*(9-10). 702-712.

Turner, R. C., & Harriet, L. A. (2003). Gender differences in cognitive and noncognitive factors related to achievement in organic chemistry. *Chemical Education Research, 80*(5), 563-568.

Verity, P.G., Gilligan, M. R., Frischer, M. E., Booth, M. G., Richardson, J. P., & Franklin, C. (2002). Improving undergraduate research experiences: Lessons from a historically black university's unusual collaboration. AAHE Bulletin, 3-6.

Walsh, M., Hickey, C., & Duffy, J. (1999). Influence of item content and stereotype situation on gender differences in mathematical problem solving. *Sex Roles, 41*(3/4), 219-240.

Ziegler, A., & Heller, K. A. (2000). Conditions for self-confidence among boys and girls achieving highly in chemistry. *Journal of Secondary Gifted Education*, 11(3), 144.

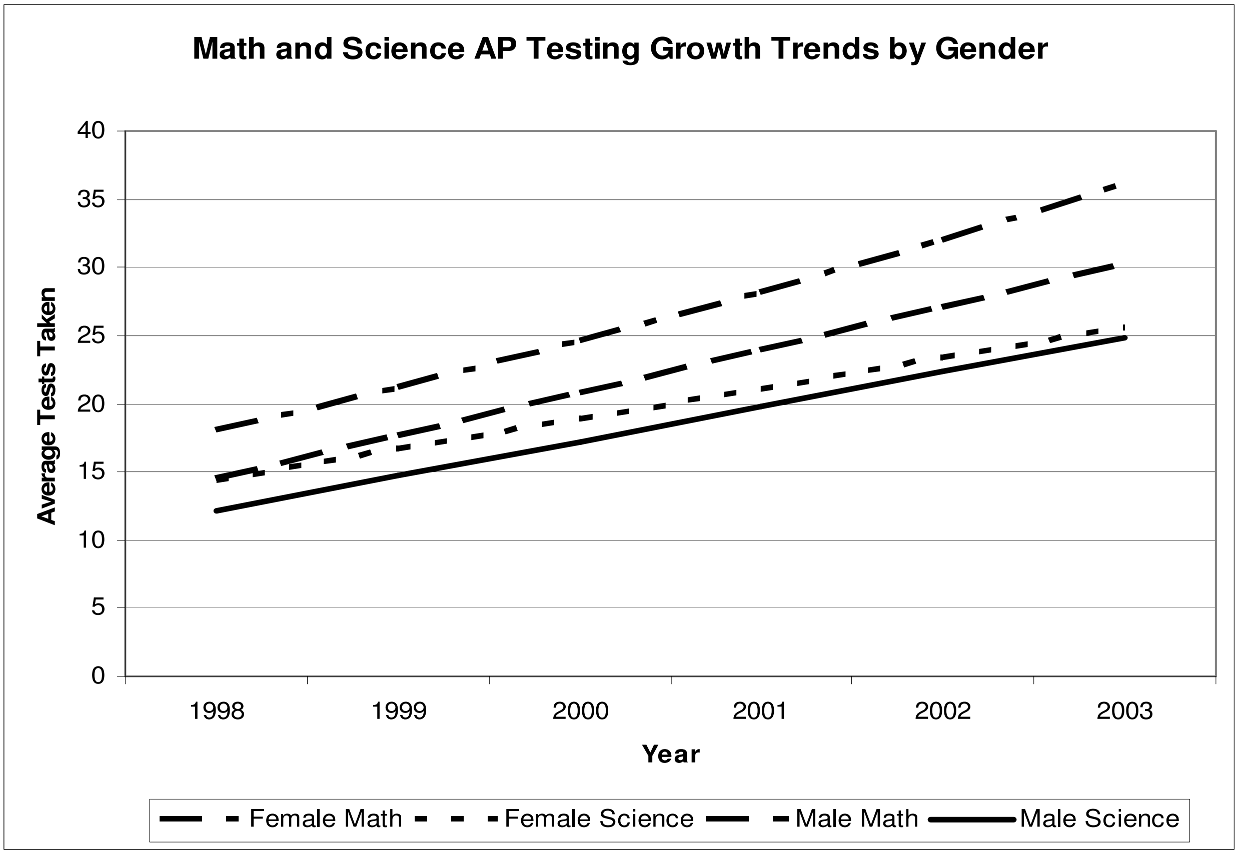
Math and Science AP Testing Growth Trends by Gender
40
35
30
25
20
15
10
5
0
Average Tests Taken
1998
1999
2000
2001
2002
2003
Year
Female Math
Female Science
Male Math
Male Science

Figure II.

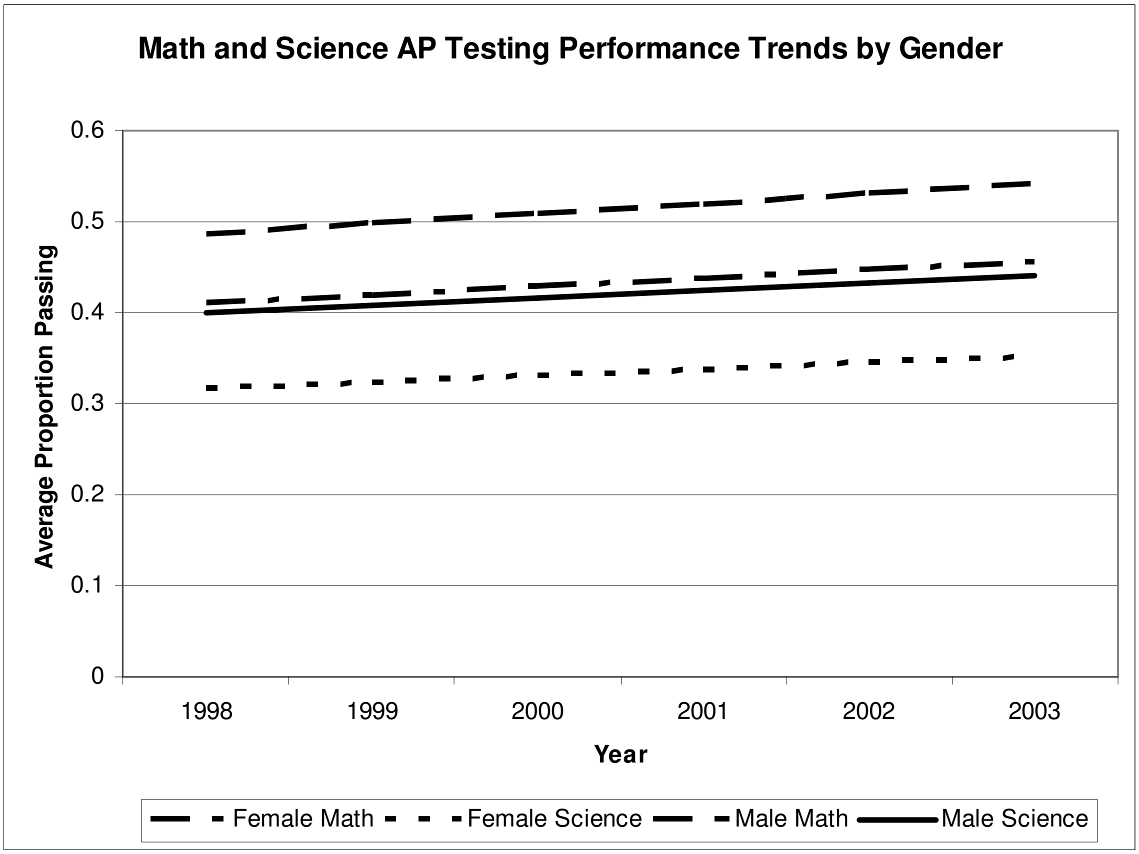
Math and Science AP Testing Performance Trends by Gender
0.6
0.5
0.4
0.3
0.2
0.1
0
Average Proportion Passing
1998
1999
2000
2001
2002
2003
Year
Female Math
Female Science
Male Math
Male Science

Figure III.