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Advancing Black Girls in STEM: Implications from Advanced Placement Participation and Achievement

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ABSTRACT

The purpose of this study was to examine Black girls' performance on advanced placement (AP) exams. Science, Technology, Engineering, and Mathematics (STEM) careers are lucrative, and there are opportunities to participate through both short-term and 4-year college degree paths. However, poor K-12 (i.e. U.S. primary through secondary school) preparation, limited course availability, and low rigor have been shown to be strong mediators of post-secondary STEM participation. Therefore, understanding how Black girls perform on various STEM AP exams provides a foundation for testing the impact of variables already identified as mediators of success. Ninth through 12th graders' AP exam scores were used from a cross-sectional sample consisting of 32,675 cases across 7 science and 3 mathematics disciplines. Cases were compared across disciplines to examine differences in participation and performance trends for Black girls on AP STEM examinations. Data were contextualized using descriptive statistics and confidence intervals of odds ratios. The results of this study suggest that Black girls participate in non-traditional STEM courses more frequently with varying levels of performance outcomes. Implications and recommendations related to this phenomenon are presented to inform research and instructional praxis.

KEYWORDS

STEM, Black girls, Achievement, Advanced Placement

Advancing Black Girls in STEM: Implications from Advanced Placement Participation and Achievement

The development of a science, technology, engineering, and mathematics (STEM) literate nation is a major goal of current United States (US) educational policy and national funding. To this end, policymakers are constantly seeking programs and policies to increase the number of STEM professionals in the US. Many of these policies seek to foster STEM interest and content knowledge in populations that are historically underrepresented in the STEM fields. Black girls represent a unique population of K-12 (i.e. U.S. primary through secondary school) learners that remain essentially untapped as a resource of potential STEM professionals. Black girls constitute a productive and growing population of K-12 learners, college students, and young professionals. For instance, Black girls outperform Black boys in most measured academic domains, with few exceptions (Young & Young, 2017; Varner & Mandara, 2013; Varner & Mandara, 2014; Whitmire & Bailey, 2010). Thus, Black girls represent a unique group of STEM learners that could potentially alter the landscape of the STEM professions by helping to diversify the future labor market.

The racial achievement gap may contribute to the lack of focus on recruiting Black girls into STEM careers given the documented underachievement of Black students compared to White students in the United States. Although the racial and gender achievement gap is one of the most persistent and pervasive issues in STEM education research, between-group comparative research designs fail to yield practical information of educational merit to neither the dominant nor the non-dominate comparison group (Young, Feille, & Young, 2017). The present study seeks to field this void through the application of a single-group summary approach.

Why are Single-group summaries of Black girl Achievement Necessary?
The current literature lacks research examining the academic achievement profiles of Black girls in specific content domains. These achievement profiles would allow researchers to develop prescriptive interventions that can guide content-based instructional practices, tailored to close knowledge gaps and eliminate the need to investigate and explain achievement gaps. Much of the available research utilizes between-group designs involving Black and White students or boys and girls (Bohrnstedt, Kitmitto, Ogut, Sherman, & Chan, 2015; Curran & Kellogg, 2016). One major limitation of ethnic or gender comparative designs, however, is that when researchers observe group differences, they are left to speculate on the cause of those differences (Dotterer, Lowe, & McHale, 2014). These activities perpetuate the trend of studying achievement gaps without yielding information that is practically significant for classroom use. Homogeneous within-group content-oriented designs could allow researchers to identify instructionally pertinent causes in achievement differences between groups by pinpointing content-specific knowledge gaps (Young, 2019). Thus, the goal of this study was to utilize an ethnically homogeneous design or single-group summary to examine the content-specific knowledge of

academically advanced Black girls in order to provide implications for STEM teaching, learning, and research.

Researchers in the medical sciences utilize single-group summaries to explicate the unique medical considerations of different demographic groups (Blank & Antaki, 2017; Najafi et al., 2015; Shaw et al., 2009). Researchers often describe a single-group summary as the estimation of the mean or risk of a single population on a particular outcome (e.g., the prevalence of disease amongst a group or mean score on a test). Within the medical research field, single-group research synthesis and meta-analyses are often conducted to summarize the effects to generalize to a specific subgroup within the population. Frequently, racial and gender characteristics are examined within the context of medical single-group summaries given the acute prevalence of particular diseases or conditions within specific demographic subpopulations (Fleury et al., 2016; Zhu et al., 2017). Generally, single-group approaches are underutilized in education or the social sciences.

Single-group summaries hold the promise to provide insights that have been systematically overlooked and possess the potential to energize a new line of methodological inquiry. Despite the promise of focused analytical approaches to support the needs of diverse learners, single-group summaries also remain underutilized in STEM education. Thus, we offer single-group summaries as a means to better ascertain the achievement of academically advanced Black girls across STEM content areas.

Purpose

The purpose of this study was to examine Black girls' science and mathematics content-specific knowledge from an ethnically homogeneous dataset representative of the United States. This study differs from other studies in two important ways. First, it is not an achievement gap analysis that seeks to compare the divergence in performance from one or more other groups, typically referred to as *gap gazing*. Gap gazing, while providing some insight into where interventions are necessary, generally does not provide information pertinent to closing the gaps in performance. Secondly, the present study provides baseline data to help benchmark the achievement of Black girls, while promoting meta-analytic thinking. Generally, educational reform efforts seek to improve the performance of all students. However, few efforts have sought to improve the performance of Black girls specifically. Therefore, this study rests in the little-understood nexus of how Black girls' mathematics and science content knowledge may influence access to high-paying STEM jobs. Specifically, if Black girls are proficient in advanced mathematics and science content in high school, they are better prepared for post-secondary STEM and subsequent careers. To this end, it is important to review the current trends in access, participation, and achievements of Black girls in Advanced Placement (AP) STEM content areas.

Black Girls and AP STEM: Access, Participation, and Achievement

In the United States, AP courses are offered to high achieving high school students as a means to earn college credit before entering post-secondary educational settings. AP exams are important indicators of STEM success for Black female

students because they require content mastery, foster higher order thinking, and are predictive of subsequent success in related content areas in college (Chajewski, Mattern, & Shaw, 2011; Marin & Halpern, 2011). The AP program, as a curriculum in the United States, is governed by the College Board. This program offers 35 specific AP courses in different content areas that are designed to be equivalent to undergraduate college courses (College Board, 2020a) These courses are typically reserved for the top 5 to 10% of students, and often require a teacher recommendation to participate (Klopfenstein & Lively, 2016). AP examination scores range from 1 to 5, but according to the College Board a score of 5 indicates that a student is exceptionally well qualified in that content area, while a score of 1 does not receive a recommendation. Each AP course is extremely rigorous, and college credit is only granted to students who earn a 3 or above on the AP examination. Unfortunately, students and/or their families are required to pay the cost for the examination, approximately $93.00 per exam (College Board, 2020b). For many students who manage to excel and to gain admittance who are living in poverty, the fee is a substantial barrier to full participation in the AP program.

Access, participation, and achievement in AP coursework, unfortunately, remain a challenge for many minoritized students in the U.S. To address financial challenges related to full AP participation, many states (e.g., California, Missouri, Texas, New York, and Florida) have taken on the fiduciary responsibly for financially challenged and underrepresented students (Davis, Slate, Moore, & Barnes, 2015; DiYanni, 2008). For instance, Texas schools implemented AP incentive programs that provide (a) AP Exam fee reductions, (b) fee waivers for students completing multiple exams in the same year, (c) professional development and stipends for AP teachers, (d) equipment grants, and (e) monetary rewards for students' passing scores on AP exams (Texas Educational Agency, 2005). Nonetheless, even after navigating the terrain to admittance into AP courses, the financial burden for Black girls who are dually marginalized as female and as students of color is compounded.

Over the last decade, educational policies and programs have increased Black student access and participation to AP coursework and exams, however data indicate that smaller proportions of Black students pass AP examinations. Specifically, some school districts eased restrictions on admission and provided exam subsidies (Smith, Jagesic, Wyatt, & Ewing, 2018). These efforts have increased student participation, but overall AP exam scores are on the decline nationally, causing many critics to suggest that the integrity of the AP program has been compromised (Holmes, Slate, Moore, & Barnes, 2015). In 1994 only 14.9% of U.S. High School students graduated with AP credit, but by 2013 this number rose to almost 40% (Malkus, 2015). The participation of Black students has also increased across most content areas, but the success of Black students does not follow the same trend.

In 2013, Black students represented 14.5% of the graduating student population, 9.2% of the AP exam participants, and only 4.6% of the students earning a 3 or above on an AP exam, the score typically needed to receive college credit (College Board, 2014). This is a substantial increase in participation compared to trends

from over a decade ago. However, although participation has increased for Black students, performance trends have not followed suit. Black student pass rates declined from 35.9% in 1997 to 29.1% in 2012 (Eugene & Hobson, 2015). Additionally, results of the 2016 exam indicated that over 70% of Black students who took an AP exam did not pass, indicating that this statistic has remained relatively consistent (Tugend, 2017). Although this paper does not examine the pervasive gaps between Black and White students, nor cross-racial comparisons, other authors have focused on this comparison (Bittman, Davies, Russell, & Goussakova, 2017; Kettler & Hurst, 2017). Ultimately, the AP trend data indicate that access and participation have increased, but achievement amongst Black students is on the decline.

Although few empirical studies have focused on Black female student access, participation, and achievement in AP courses, trends can be extracted from national reports on AP performance. According to data from the College Board, Black female students under-participate in AP STEM content exams. In a recent report comparing participation of students with AP potential (students identified with the capacity to score a 3 on the AP exam), only 35% of Black female students took an AP mathematics or science exam when given the opportunity (College Board, 2015). Given that little is known about the participation and performance trends of Black girls, we seeks to fill this knowledge gap.

Analytical Framework

For the present study we seek to critically examine the intersections between race, gender, and achievement outcomes to inform instruction and policy for Black girls in STEM. Critical quantitative inquiry was chosen as a means to achieve this goal. The critical quantitative researcher has two tasks: "1) Use data to represent educational processes and outcomes on a large scale to reveal inequities and to identify social or institutional perpetuation of systematic inequities in such processes and outcomes, and 2) Question the models, measures, and analytic practices of quantitative research in order to offer competing models, measures, and analytic practices that better describe experiences of those who have not been adequately represented" (Stage, 2007, p. 10). Thus, this study rejects conventional comparative traditions, in favor of a single group or specific group approach.

Much of the available research on the achievement of Black girls utilizes between-group designs involving Black and White students or male and female students (Young & Young, 2018; Young, Young, & Capraro, 2017, Young, Young, & Ford, 2017). These activities perpetuate the trend of *gap gazing* and fail to yield information that is practically significant for classroom use. This research study does not make ethnic and gender comparisons across groups. These types of comparisons, although normative, often fail to yield information relevant to teaching, learning, and subsequent achievement of individual groups of learners. Rather than speculate on the causes of between-group differences, we place Black girls' STEM content knowledge at the forefront of the discussion. A strength of this approach in quantitative research is that more of the group's internal variability can be examined (Carter & Hurtado, 2007). Thus, the entire discussion of the results

from the analysis is focused on how to better support Black girls specifically, not in comparison to Black male or White female peers.

Critical race theory (CRT) has been identified as a useful lens for identifying and addressing policy gaps for racial minorities by bringing race to the forefront, breaking down assumptions about racial groups, and being critical of systems and policies (Solórzano, 1998). Many researchers have used CRT frameworks for qualitative methods, but the philosophical framework can be applied to quantitative research as well (Carter & Hurtado, 2007). In the present study, we applied the concept of intersectionality under the umbrella of Critical Race Feminism (CRF) as an analytical and interpretive framework. Feminist epistemologies and race-based epistemologies tend to work in isolation and with a narrow focus on White females and Black boys respectively, which causes the needs of Black female students to fall through the cracks (Evans-Winters, 2005). For example, prominent works in feminist scholarship historically failed to include the voice of Black girls (Ladner, 1987; Scott-Jones & Clark, 1986). The lack of intersections between the two epistemologies creates a significant need for more scholarship in the field of education that focuses on the Black female subgroup. Thus CRF in education may provide "legal and academic stratagem for studying and eradicating race, class, and gender oppression in educational institutions" (Evans-Winters & Esposito, 2010, p. 19).

Based on the utility of CRF as an interpretive lens for quantitative research, this study was guided by two research questions:

1. What are the participation and achievement patterns of Black girls in Advanced Placement Science and Mathematics exams?
2. What are the odds of successfully earning college credit on individual Science and Mathematics Advanced Placement exams for Black girls?

Data

In 2012, Black girls completed 150,417 Advanced Placement (AP) examinations across several independent content areas (College Board, 2013). Within the standardized testing culture of the United States, the term *Black* is commonly used as an inclusive racial demographic category for students of African descent that were born in the United States. This term is inclusive of multiple ethnic groups including but not limited to African American, African, Jamaican, and Haitian students. Thus, the term Black is used to represent these groups of students in the present study. The AP program contains 35 courses/examinations across 20 subject areas and is scored on a scale of 1-5 with a score of 3 generally accepted as representing a passing score (Jackson, 2010). The data for this study were extracted from the 2012 administration of the Advanced Placement exam's archived data sets provided by the College Board (College Board, 2013). The first step was to remove all students except Black girls from the dataset. The remaining cases (N = 97,717) constituted all Black female participants in AP examinations. There were 20,919 9th or 10th grade students; 36,272 11th grade students; 39,043 12th grade students; and 1,483 non-high school students. However, given the STEM focus of this investigation, only data from Black female students completing the seven science exams (i.e., Biology,

Chemistry, Environmental Science, Physics B, Physics C_1, and Physics C_2) and the three mathematics exams (i.e., Calculus AB, Calculus BC, and Statistics) were used in the present study. This represents data from 32,675 Black female students used in the analysis below.

Data Analysis

Four types of analyses were used to contextualize the data and to provide interpretable information. The first were descriptive statistics to understand the spread and center of the data. The second was the 95% confidence intervals for the point estimates. Confidence intervals are an effective analytic strategy because they provide insights into the accuracy and spread of the point estimate and whether it diverges from point estimates obtained on other tests (Capraro, 2004). The third analyses were graphs of exam participation distributions to provide a context for interpreting student attainment. Finally, odds ratios were calculated to provide estimates of performance within science and then within mathematics. To offer pertinent background information, the following Advanced Placement examination related descriptive statistics were provided: science and mathematics exam participation frequencies, Black girls' score frequencies (1 to 5), and mean examination scores for Black girls. For this study scores in the range from 3 to 5 were considered passing and scores below 3 were considered not earning college credit or failing.

To properly investigate the achievement of Black girls on STEM-related AP exam content, the odds ratios for science and mathematics related exams were computed. The odds ratio is used to determine whether the probability of an event is the same or differs across two groups (Bland & Altman, 2000). Thus, the examination investigated whether the likelihood that Black girls will earn a passing score on specific science and mathematics exams is the same or differs across examinations. For example, is the probability of Black girls earning a score of 3 or more on the Calculus BC exam the same as the probability of earning a 3 or more on the other AP mathematics exams? These results have substantial implications for teachers, administrators, parents, guidance counselors, researchers, and especially Black girls.

The misinterpretation of odds ratios contributes to their underutilization in the social sciences. The odds ratio is one of several statistics used to assess the risk of a particular outcome if a certain factor is present (Schmidt & Kohlmann, 2008). Here we used the AP mathematics exams as an exemplar for interpreting odds ratios in the present study. In our study, the odds ratio facilitates estimates of how much more likely it is that Black girls taking the Calculus BC exam will score a 3 or more compared to Black girls taking other mathematics AP exams. Values for the odd ratio range from 0 to infinity; however, a value of 1 represents no relationship. Using the above Calculus BC example:

OR = 1, no relationship
OR < 1, less likely to pass BC Calculus
OR > 1, more likely to pass BC Calculus

Some researchers suggest that interpreting the magnitude of the odds ratios is somewhat ambiguous, so this study employs a comparison strategy that utilizes benchmarks similar to those proposed for interpreting Cohen's *d* effect sizes. According to Chen, Cohen, and Chen (2010), odds ratio values of 1.68, 3.47, and 6.71 are equivalent to Cohen's *small*, medium, and *large* effects respectively. In addition, 95% confidence intervals were calculated to determine whether or not the odds ratio values were statistically significantly different from 1. If the odds ratio statistically significantly diverges from 1, then the 95% confidence interval will not include 1. To enhance the interpretation of the results, 95% confidence intervals of the odds ratios were also plotted.

RESULTS

The descriptive statistics are summarized in Table 1. The mean scores across five science subjects were all well below the minimum passing score of a 3 or better on the AP exam: Biology, Chemistry, Environmental Science, Computer Science, and Physics B. More specifically, the means were all less than 2. However, two bright spots were evident. Both Physics C exam mean scores, Electricity and Magnetism, and Mechanics, exceeded 2 with Electricity mean score only .3 of a point away from the mean passing score. Given the inclusive nature of a measure of central tendency, having mean group scores at or above the minimum passing score is a strong indicator of high overall group performance.

Contrarily, having mean scores substantially below the minimum score is indicative of lower overall group performance. For example, all mean scores on the science exams were below the minimum passing score of 3.0, thus indicating low group performance overall. Few Black girls earned college credit from any of the science AP courses based on the mean group performance. The bias-corrected Hedges' *g* (1.069) and the percent difference (70%) were calculated to characterize the magnitude of the difference between the lowest and highest science performances. The Hedges' *g* indicated that there was one standard deviation or a 70% difference in attainment. While selectivity can account for some of that difference, it is not the full story. Because that course is often more rigorous and occurs later in their educational career, one might conclude that students taking and passing Electricity and Magnetism could represent some select group of Black girls who might have also scored well on other AP exams. However, the subgroup experiencing success is too small to influence the whole group mean scores.

Mean mathematics performance followed a similar trend. Calculus AB is the less rigorous of the calculus options, but most frequently attempted. Statistics is the second most commonly taken mathematics exam. Statistics, while rigorous, is not one of the courses required for STEM majors nor is it a prominent course for mathematics majors. Mean scores on the Calculus AB and Statistics exams were less than the mean score of 3 necessary to receive college credit at most colleges and universities. The mean scores on the Calculus BC exam were only .08 of a point away from the score needed to earn college credit. This indicates that the overall performance of Black girls on this exam was close to a score of 3.0, which would earn college credit for Calculus 1 and 2. The bias-corrected Hedges' *g* (1.00) and the percent difference (64%) were calculated to characterize the magnitude of the

difference between the lowest and highest mathematics performances. The Hedges' g indicates that there is one standard deviation or a 64% difference in attainment when comparing Calculus BC and Statistics attainment.

Achievement Patterns on AP Science and Mathematics

Figures 1 and 2 present individual score frequencies on science examinations for Black girls. Due to the large discrepancy in participation across different science examinations, the score frequencies were divided into two charts. The first figure presents the science exam score frequencies for exams with more than 2,000 participants. This figure includes Biology, Chemistry, Environmental Science, and Physics B. The data in Figure 1 suggest that the majority of Black girls earned a score of 1 on each exam. Furthermore, the score frequency decreases as the scores increase. Hence, there are substantially more scores of 1 than scores of 5 across the four science exams presented in Figure 1. It is also important to note that these exams had the largest number of attempts, all of which were attempted more than 2,000 times.

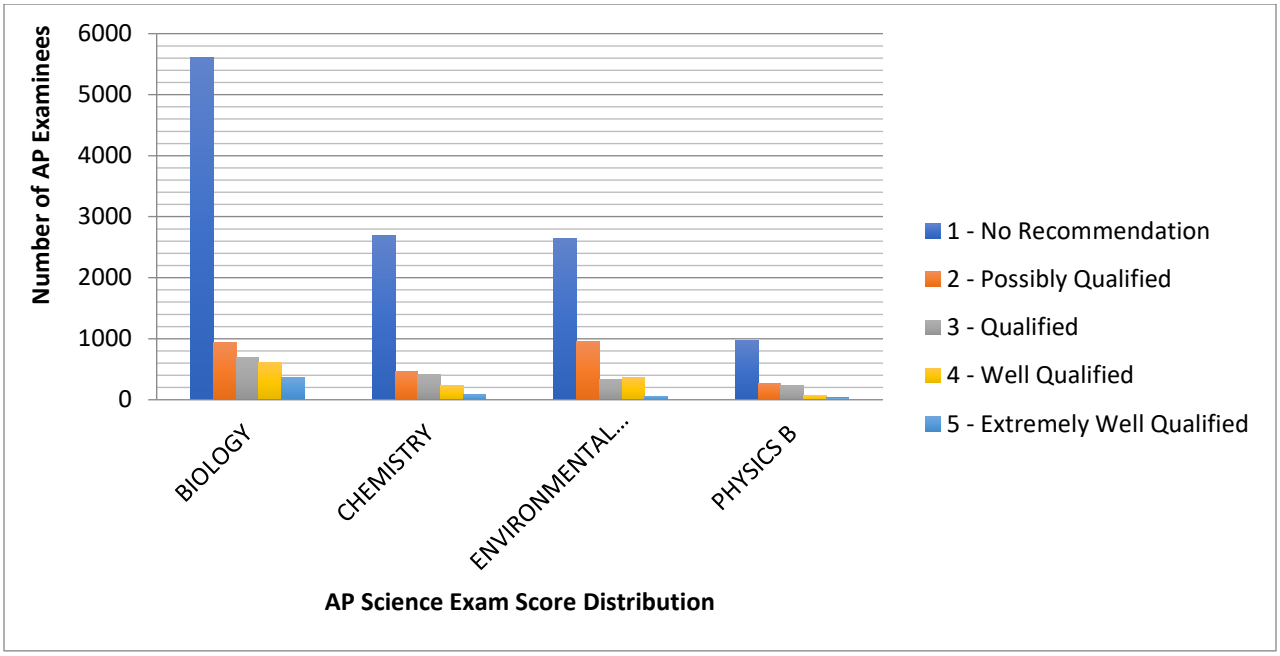

Figure 1. Score Frequencies for Black girls in Biology, Chemistry, Environmental Science, and Physics B

Table 1. Descriptive Statistics of AP Exam Scores Across Science and Mathematics Tests for Black Girls

	Science							Mathematics		
Dsc	Biology	Chemistry	Environment	Computer	Physics B	Physics C_1	Physics C_2	Calc AB	Calc BC	Statistics
N	8210	3876	4347	252	1571	89	270	7791	1026	5243
M	1.68	1.59	1.67	1.63	1.68	2.70	2.31	1.81	2.92	1.78
SD	1.17	1.03	1.02	1.24	1.00	1.34	1.28	1.27	1.52	1.05
CI	1.65-1.71	1.56-1.62	1.64-1.70	1.48-1.70	1.63-1.73	2.42-2.98	2.16-2.46	1.78-184	2.83-3.01	1.75-1.81

Note. Dsc= descriptive statistic; 1= Electricity and Magnetism; 2= Mechanics; CI= 95% confidence interval for the mean

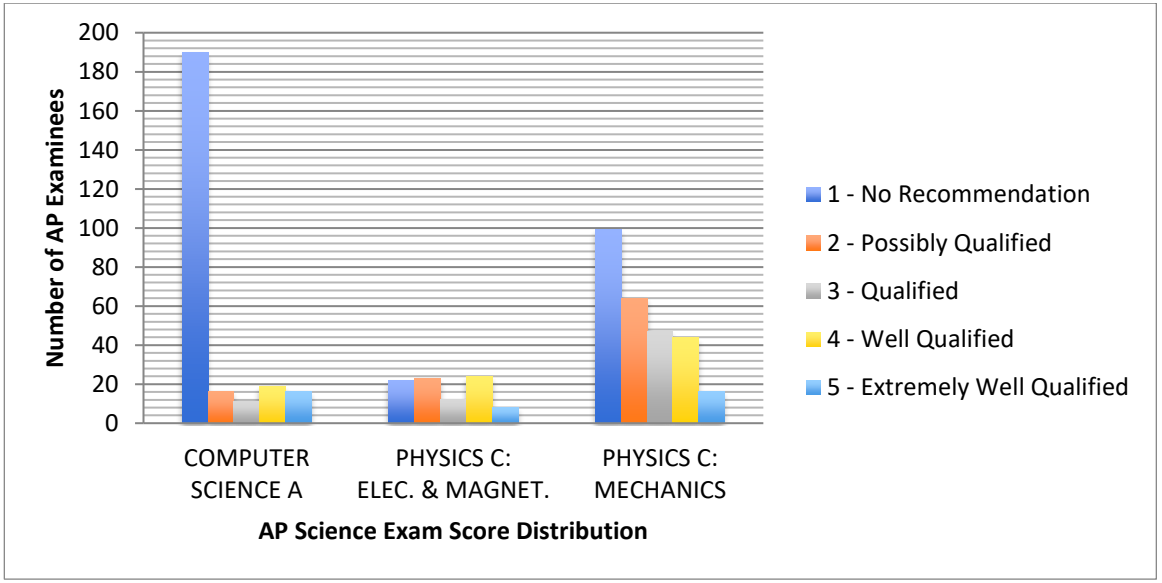

Figure 2. Score Frequencies for Black girls in Computer Science, Physics: Electricity and Magnetism, and Physics: Mechanics

The data in Figure 2 follow a similar trend, with the exception of Physics C: Electricity and Magnetism. Unlike the other science exams, the distribution is not as skewed, and a score of 4 is the mode for the dataset. Substantially more students scored a 1 on the computer science exam compared to the frequencies observed in the other content areas in Figure 2. Figure 3 presents the score frequencies for the mathematics exams.

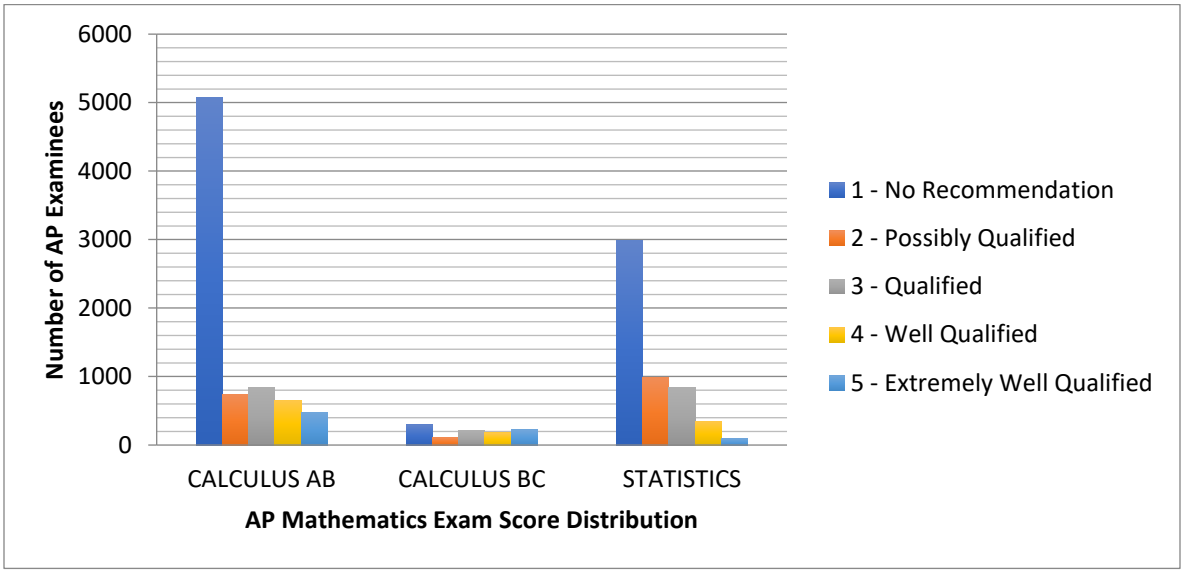

Figure 3. Score Frequencies for Black girls in Calculus AB, Calculus BC, and Statistics

Score frequencies for mathematics represent a consistent mode score of 1. However, the distribution of scores for the Calculus BC exam is not skewed; rather, the distribution is relatively flat. Furthermore, the data in the figure suggest that far fewer Black girls attempted the Calculus BC exam compared to the other mathematics AP examinations. The aforementioned data indicate that Black girls participate and complete AP exams in STEM content with different pass rates. The results provided by the odds ratios may help to further explicate the trends observed. Figure 4 presents the 95% confidence intervals for the odds ratios of Black girls' passing scores on the science AP exams.

The data in Figure 4 suggest that the majority of the odd ratios hover around 1. Furthermore, the 95% confidence intervals for Biology, Chemistry, Computer Science, and Physics B all subsume 1. This suggests that the odds ratios for these scores do not statistically significantly diverge from 1. Thus, the probability of earning a score of 3 or more on the AP exam is not different for these exams compared to the other science exams. However, the Environmental Science 95% confidence interval does not intersect the value of 1, and the odds ratio is less than 1, which suggest that the odds of Black girls scoring a 3 or more on this exam are less than the odds of scoring a 3 or more on other exams. Of the two Physics C exams, (1) Electricity and Magnetism (odds ratio= 4.02) and (2) Mechanics (odds ratio = 2.73), the odds ratio of the first exam was relatively large with the second was relatively small. Additionally, neither confidence interval included the value 1.

Thus, each statistically significant diverges from 1 indicating that the odds of Black girls scoring a 3 or more on these exams are higher than the odds of Black girls scoring a 3 or more on other AP science exams. It is important to note that the 95% confidence intervals for these two physics exams have wider bands. The width of the bands is based on the inverse relationship between the standard error and sample size, which suggests either the standard error is large or the sample size is small. Compared to the other science exams, the two Physics C exams had much smaller samples of only 89 and 270 test takers.

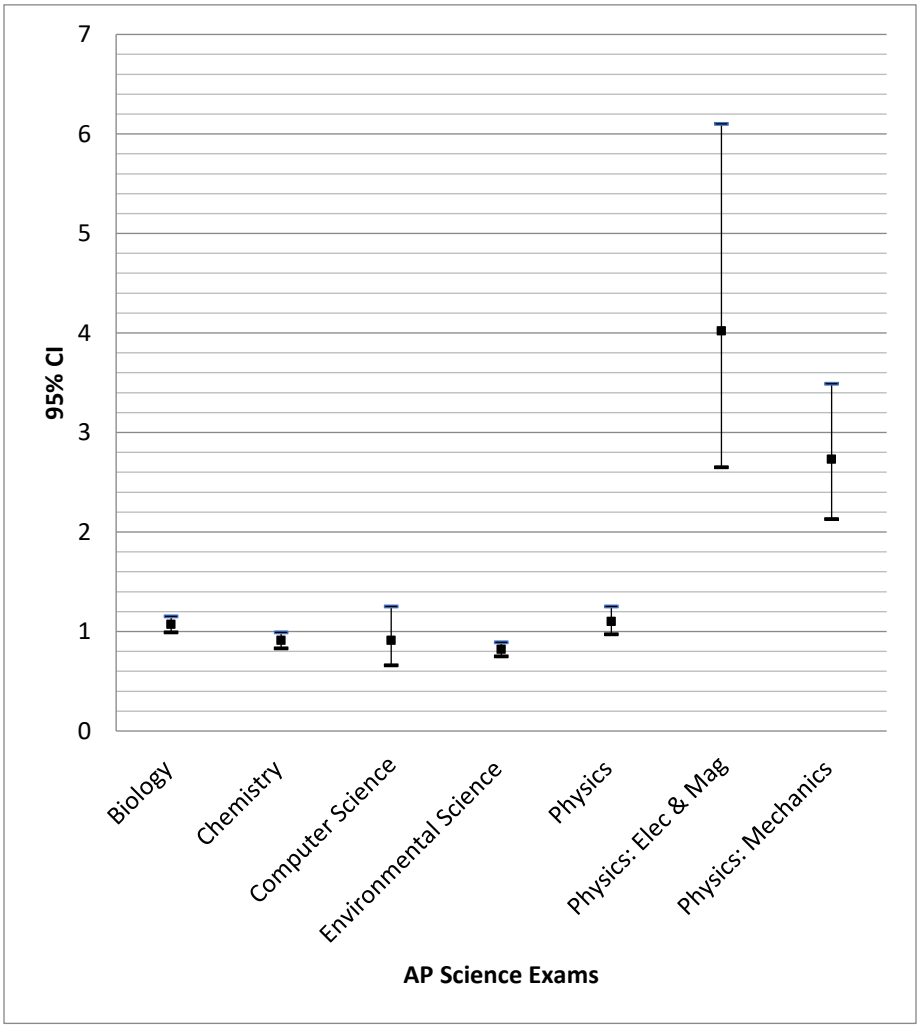

Figure 4. 95% Confidence Intervals for Odds Ratios of Black girl passing scores on Science Exams

The odds ratios for the mathematics exams were presented in Figure 5. The data in Figure 5 suggest that the odds of earning a score of 3 or more on a mathematics AP exam are much more contingent on the examination that Black girls attempt. None of the 95% confidence intervals include 1. Thus, all of the scores diverge statistically significantly from the value of 1. Therefore, the odds of passing are statistically significantly different across exams. The Calculus AB and Statistics exams both have odds ratios less than 1, which suggest that, the likelihood of Black

girls earning a 3 or more on these exams is less than the odds for other exams. In addition, the width of the bands for these exams is much narrower than the width of the confidence bands for the Calculus BC exam. This indicates a more precise measure of the point estimate. The narrower the band, the larger the sample size and/or smaller the standard error. This is appropriate given that the number of test takers for the Calculus AB and Statistics exams is much larger than the number of students who attempted the Calculus BC exam. Finally, the odds ratio for the Calculus BC exam is 4.57; based on the benchmarks mentioned above this value represents a medium to large effect size. Thus, there is a medium to large positive influence on Black girl passing scores for Black girls attempting the Calculus BC exam.

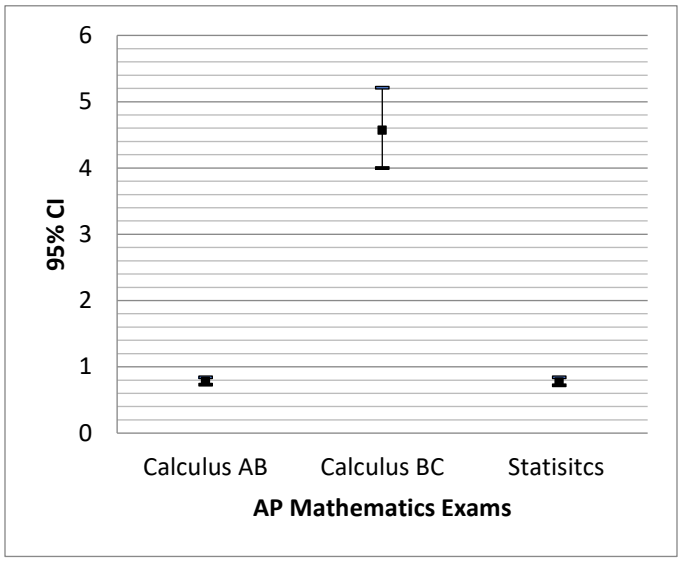

Figure 5. 95% Confidence Intervals for Odds Ratios of Black girl passing scores on Mathematics Exams

DISCUSSION

The results of this study suggest that Black girls participate in less rigorous mathematics and science courses more frequently than they do in more rigorous mathematics and science courses. Here we define rigor as standards, skills, and knowledge that prepare Black girls for STEM courses and careers. Hence, Black girls are not taking AP coursework and exams that will best prepare them for STEM careers as frequently they are taking other mathematics and science exams. Participation frequency data suggest that within the AP sciences exams, Black girls tend to attempt the AP Biology exam most frequently. Because biology is a common course for healthcare professionals, this trend is consistent with prior research that suggests that students of color and women tend to have an affinity toward careers in the healthcare professions (Bowen, Kurzweil, & Tobin, 2005; University of the Sciences, 2012). Moreover, the AP science courses and exams with more direct applications to non-healthcare STEM professions were attempted less frequently by Black girls.

Specifically, the physics and computer science courses were attempted substantially less frequently, which may reflect the results of prior studies which suggest that girls feel the most out of place in computer and physical science related STEM fields (Stout, Dasgupta, Hunsinger, & McManus, 2011). However, it is important to note that Black girls scored substantially higher on both Physics C exams, which are directly associated with engineering and other STEM professions. Similar participation trends were observed in mathematics, with Black girls participating in Calculus AB seven times and Statistics approximately five times more frequently than the more rigorous Calculus BC exam. Calculus, unlike statistics, is a core mathematics course for engineering proficiency; thus, participation in high school calculus has substantial benefits for future STEM success (Nortvedt & Siqveland, 2018). Two conflicting explanations may explicate the participation trends presented in the present study: access and avoidance.

Access to AP courses is not isolated to issues of course offerings but also encompasses college/career counseling and mentorship. Low income students of color and their parents consistently lack adequate counseling about the courses needed for acceptance at different colleges and in different majors (Schneider, Judy & Mazuca, 2012). Access to qualified teachers is another important consideration in course selection decisions. Many students benefit from role models with similar backgrounds and experiences; hence, there is a direct relationship between the lack of highly qualified teachers of color and the number of students of color who choose careers in mathematics and science (Toolin, 2003). The mentorship that these teachers provide enables many Black girls to envision themselves completing AP courses because they have an aspirational role model to emulate.

Avoiding rigorous mathematics and science courses is common amongst all high school students, but avoidance is uniquely problematic for Black students (Riegle-Crumb, 2006). External frames of reference can explain some of the avoidance patterns related to Black girls and AP mathematics and science courses. According to Skaalvik and Skaalvik (2002), external frames of reference refer to comparing one's own ability to the abilities of peers. Girls' decisions to take advanced mathematics and physical science courses are highly predicated on how well their female peers performed in the same classes the previous year (Riegle-Crumb, Farkas, & Miller, 2006). Thus, girls tend to avoid courses that their female peers find difficult. An analogous focus of this investigation was the achievement of Black girls on AP examinations. Therefore, if access and avoidance are constraining participation, these constraints must also be considered as they relate Black female achievement (i.e., if representative populations of Black girls do not participate, one cannot measure their overall group achievement).

STEM proficiency represents a student's qualification and preparation in STEM, measured most often by student performance on standardized tests (Lichtenberger & George-Jackson, 2013). In our study, STEM proficiency was assessed by a student's ability to earn a score of 3 or higher on the AP exam. Across all exams investigated, Black girls' mean scores are below 3, which indicate that the mean scores for Black girls on all the exams are below passing. Additionally, aside from the Calculus BC, Physics: Mechanics, and Physics: Electricity and Magnetism exam,

all other mean scores are less than 2. One benefit from plotting and visually inspecting confidence intervals is the ability to identify statistically significant difference based on the amount of overlap between the confidence bands and pertinent benchmarks (Cumming, & Finch, 2005). This provides a better characterization and interpretation of the performance of Black girls across content areas.

For example, data from the mean score confidence intervals also suggests that all scores except for the Calculus BC exam are statistically significantly different from 3, given the lack of inclusion of the score of 3 in the confidence interval range. For example, the biology confidence intervals extend from 1.65-1.71, and do not include 3; thus, it is statistically significantly different from 3, whereas the Calculus BC exam confidence intervals extends from 2.83-3.01, which includes the value of 3 and is not statistically significantly different from 3. Hence, Black girls are earning scores far from the standard needed to earn college credit at most colleges and universities in all content areas except Calculus BC. The results of the mean scores compare Black girl performance to the AP standard, while the odds ratio examines within-group performance on AP mathematics and science examinations. We argue that combined these data provided more relevant data to inform instruction.

The 95% confidence intervals for the science exam odds ratios suggest that the odds of passing were similar for all exams except Environmental Science, Physics: Mechanics, and Physics: Electricity and Magnetism. Odds ratios that subsume the value of 1 are indicative of non-statistically significantly higher or lower odds. Because the Environmental Science AP exam confidence interval is less than 1 and does not intersect 1, it suggests that Black girls are 0.82 times less likely to pass the Environmental Science exam compared to other science exams. Furthermore, based on the same logic, Black girls are 2.73 times more likely to pass the Physics: Mechanics exam and 4.01 times more likely to pass the Physics: Electricity and Magnetism exam. This result is unique because these exams have a much lower participation by Black girls. For instance, only 89 girls attempted the Physics: Magnetism and Electricity exam, and subsequently this exam had the highest passing odds amongst the science AP exams compared. It is important to note that the Physics: Mechanics and Physics: Electricity and Magnetism exams are specialized exams that are not offered in many high schools. These exams also represent two of the most rigorous science exams given the strong connection to STEM-related content. Additionally, these participants may represent a unique group of students with very specialized instructional opportunities.

Within the mathematics exams, Black girls were 0.78 times less likely to pass the AB Calculus exam and 0.77 times less likely to pass the Statistics exam. However, the Calculus AB exam and the AP Statistics exams represent the majority of the mathematics exams attempted by Black girls. Black girls were 4.57 times more likely to pass the more rigorous Calculus BC exam, yet participated far less frequently in the Calculus BC exam. These results warrant continued investigation to further explicate these trends. One explanation is that given the more rigorous exams are not offered in most high schools (Perna et al., 2015), access to these exams is more restrictive, and only the Black girls with superior aptitude attempt

them. An alternative hypothesis is that many Black girls may receive instruction from teachers that lack the content knowledge and other qualifications to adequately prepare them for AP exams in STEM content areas.

CONCLUSION

In conclusion, it is our hope that the trends presented in this study help to better explicate the specific academic strengths and needs of high achieving Black girls pursuing STEM-related fields of study. Many variables can account for the pattern of performance for Black girls across all the AP mathematics and science subject tests. However, the reality is that girls are underrepresented in post-secondary STEM programs and in subsequent STEM professions. While performance on an AP examination, in and of itself, does not represent a barrier, it is potentially a strong indicator of the lack of preparedness and opportunities for success in post-secondary STEM coursework. This problem is complex, and there are likely many plausible and testable variables that can affect AP test score performance and that mediate Black girls' interest in pursuing a post-secondary STEM career.

Based on the results of the present study it is our hope that educators and researchers will begin to look for opportunities to increase AP course efficiency by mapping student course grades onto AP exam scores to identify possible discontinuities. We proffer that this practice would help to identify classroom and school level inefficiencies that can be rectified to improve the performance of Black girls on AP STEM exams. Additionally, based on the performance trends of Black girls taking the more rigorous AP exams we recommend further investigations as to the factors influencing the success of this subset of Black female learner. The present study represents an initial investigation of the unique STEM achievement trends of Black girls taking AP examinations; thus, we recommend others to use these data to better inform the teaching and learning of Black girls in advanced STEM content areas.

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