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SAT patterns and engineering and computer science college majors: an intersectional, state-level study

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Abstract

Background: Numerous efforts worldwide have been made to increase diversity in engineering and computer science (ECS), fields that pay well and promote upward mobility. However, in the United States (U.S.), females and students from underrepresented racial/ethnic minority groups (URM) still pursue ECS training far less than do their peers. The current study explored sex and racial/ethnic differences in ECS college enrollment as a function of math and verbal SAT score patterns (balanced or imbalanced) using an intersectional approach within a U.S. context. Data represented a census of students who took the SAT, graduated from all Virginia public high schools between 2006 and 2015, and enrolled in a 4-year college ($N = 344{,}803$).

Results: Our findings show, within each sex, URM students were at least as likely as their non-URM peers to enroll in ECS programs when they scored within similar SAT score ranges. Students were more likely to enroll in ECS programs if their SAT profile favored math, compared to students with similar math and verbal SAT scores (balanced profile). This overall pattern is notably less pronounced for URM female students; their propensity to major in ECS appeared to be largely independent of verbal scores.

Conclusions: Our findings inform strategies to diversify ECS enrollment. If programs continue to emphasize SAT scores during admission decisions or if more systemic issues of resource allocation in secondary schools are not addressed, other efforts to broaden participation in ECS programs may fall short of goals. Our findings also highlight the importance of considering the intersection of sex and race/ethnicity for recruitment or other educational promotions.

Keywords: Engineering, Mathematical achievement, Sex and race/ethnicity, Postsecondary education, Intersectionality

Introduction

Diversification of the STEM (Science, Technology, Engineering, and Mathematics) workforce is a compelling international concern. A diverse workforce is likely to develop more creative solutions to complex problems (Wulf, 2002) and increases equitable access to high-paying careers across demographic groups (Pfatteicher & Tongue, 2002). Diversification, however, remains a stubborn challenge in the United States (U.S.) and across much of the world (UNESCO, 2021). In the U.S., women are particularly underrepresented in the physical and engineering sciences, garnering only 20–25 percent of undergraduate degrees in physics, engineering and computer science in 2018, despite being overrepresented in 4-year colleges (National Center for Science & Engineering Statistics, 2021). Similarly, Hispanic and African American students earned fewer than 10 percent of engineering and computer science (ECS) degrees,

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despite comprising about 30 percent of the U.S. national population and about 17 percent of the 4-year college-going population in 2014 (National Science Foundation, 2017). Similar low rates of women earning engineering bachelor's degrees are found in many countries and regions across the world (Gupta, 2019; UNESCO, 2015), while ECS underrepresentation or exclusion of minority or stigmatized groups is likewise an international concern (Delaine et al., 2016). These discrepancies have motivated calls for a science of broadening participation (SoBP) in STEM (Husbands Fealing & McNeely, 2016; McNeely & Husbands Fealing, 2018). In this article, we focus on ECS, fields that have been particularly slow to diversify in many countries, including the U.S., and on entry into the field, through undergraduate ECS concentration.

Conceptual framework

We approach the study of broadening ECS participation using an intersectional framework. Broadly, intersectionality refers to the "nexus of social, political, and cultural identifiers that can differentially affect lived experiences" (Tao & McNeely, 2019, p. 182; citing Crenshaw, 1989, 2014), and thus influence educational and career decision-making. Rooted in Black feminist theory (Crenshaw, 1989), intersectionality considers individuals' multiple group identities and experiences to understand overlapping discrimination or prejudice they might face, highlighting that demographic groupings are not monolithic. For example, whereas all women studying engineering may experience sex-related challenges (e.g., discrimination, stereotype threat) being in a male-dominated field (Steele et al., 2002), women from underrepresented racial/ethnic minority (URM) groups may experience additional or different biases or frictions, such as in the U.S., feeling alienated from an ECS curriculum that reflects White Majority values (Bonous-Hammarth, 2000). Intersecting experiences of varied structural frictions suggest that different strategies may be needed to broaden and diversify ECS participation.

Despite long-standing recognition of the "double bind" and related intersectional ideas (e.g., Malcolm et al., 1976), most research on broadening STEM and ECS participation in particular has focused on factors of sex and race/ethnicity within a "single axis paradigm" (Cech, 2022): that is, focusing on or considering only one demographic identity at a time (see for example, Mann & DiPrete, 2013; Moakler & Kim, 2014). In some notable exceptions, Tao and McNeely (2019), using National Science Foundation data spanning 30 years, documented differential rates and reasons for leaving engineering careers for U.S. men and women of four race/ethnicities, with White men having the highest "stay" rates; while women overall had lower stay rates than men, White women were more likely to stay than African and Asian American women and Hispanic women had equivalent retention rates to Hispanic men. Black and Hispanic men and women cited "job not available" as the primary reason for switching fields, compared to Whites and Asian American men, while Asian American women ranked "job not available" as a second most endorsed reason (Tao & McNeely, 2019). These differences suggest substantially different experiences, barriers and rewards to an engineering career depending on intersectional group membership.

A pivotal gatekeeper to ECS workforce participation is academic training. In the U.S., while women and most non-White groups are severely underrepresented in undergraduate ECS majors, another example of an intersectional study showed that low representation may not reflect lack of interest for some groups. With academic preparation controlled, Black male students were one and a half times more likely to major in physical science or engineering than White male students (Riegle-Crumb & King, 2010). Similarly, the gap between Black females and White males enrolling in a physical science or engineering major was smaller than the gap between White females and White males, after controlling for covariates. A more recent population-level study found more severe underrepresentation with intersections of minoritized subgroups (i.e., URM females; Knight et al., 2020). In this study, which assessed ECS enrollment in one U.S. state across a decade, White and Asian American females enrolled in ECS at higher rates than URM females. These studies suggest that at a critical entry point into eventual engineering careers, as a group, males and females of different races/ethnicities have different proclivities, motivations, and possibly barriers to study ECS.

Therefore, the current investigation utilized intersectionality as a framework to explore patterns of ECS enrollment among URM females, non-URM females, URM males, and non-URM males using statewide population-level data across 10 years ($N = 334{,}803$ students). By including more than one dimension of students' identity, the current study provides a more nuanced picture of ECS major choice when students have similar academic preparation.

Complementing the intersectional framework is Perna's (2006) model of student college choice, which considers both students' demographic characteristics, such as sex and race/ethnicity, *and* their academic achievement as important factors in determining academic attainment. This model, which integrates economic and sociological perspectives, theorizes that the patterns of educational attainment that are partly influenced by students' academic achievement are not universal, but rather vary across sex and race/ethnicity. The current study used

students' SAT scores as an indicator of academic achievement and explored whether the relations between SAT scores and students' ECS enrollment varied based on the intersection of sex and race/ethnicity. Importantly, we did not only examine score value, but explored achievement patterns of relative strength in math and language abilities.

SAT patterns and ECS enrollment

In the U.S., colleges typically use the math portion of the SAT or the American College Test (ACT) to gauge preparedness for math-intensive majors, with many programs specifying critical score ranges or cutoffs for admission (Evans, 2015), and these test scores do indeed predict ECS study (Lundy-Wagner et al., 2014; Min et al., 2011). Thus, some researchers argue that the differences in math preparation—as indexed by math portions of standardized tests—between White males and other students explain why females and URM students are underrepresented in ECS fields (Tyson et al., 2007). Early studies of SAT patterns showed distinct advantages for males in math SAT, which in turn strongly predicted a math-intensive scientific college major (Goldman & Hewitt, 1976); for example, at the high ends of the scale, the male–female ratio of SAT math scores in the top 1% and top 0.01% of the distribution was 2:1 and 4:1, respectively (Ceci & Williams, 2011; Wai, et al., 2010). Similarly, a math preparation gap as measured by these exams is also present between racial/ethnic groups, as White and Asian American students tend to score higher on the math SAT compared to their Black and Hispanic peers (Snyder et al., 2019).

Although math proficiency certainly is important for ECS success, the SAT verbal subtest should also be considered. While most research focuses on students' math preparedness in relation to ECS enrollment, a small number of studies suggest that students who excel at both math and language arts may represent a student profile with broader or more diverse interests, compared to students who excel in one but not both academic domains (Davison et al., 2014; Wang et al., 2013). More specifically, the process of choosing a major—and likewise career—can be viewed as making a decision among competing alternatives (Davison et al., 2014). When students have both high math and verbal scores compared to those who have high math but moderate verbal scores, their likelihood of choosing a non-math intensive major is higher because their high verbal ability increased expected success and attractiveness of non-math intensive fields. Davison et al. (2014) found that higher SAT verbal scores were related to a lower likelihood of majoring in ECS, whereas SAT math scores were related to a higher likelihood of choosing ECS majors. Similarly, Wang et al. (2013) found that 33-year-old adults, who as students had scored high on both math and verbal SATs (balanced profile) in 12th grade, were less likely to have chosen a career in STEM compared to those with high math but moderate verbal scores (imbalanced profile). Although students in Wang et al.'s (2013) sample (83% White and Asian American) who had a balanced achievement profile might have had more options, they were much more likely to have been non-URM; this assumption may not apply equally to URM students. In the current study, we extend this literature by taking an intersectional approach to examine sex within race/ethnicity across many years of an entire state-wide, public school student population.

The current study

In this paper, we aimed to answer two research questions. (1) What is the likelihood of URM males and females (principally African-American and Hispanic students) and non-URM males and females (White and Asian American students) enrolling in an ECS program when they scored in the same SAT score ranges? (2) Would students with math-favored, imbalanced achievement (i.e., high math but moderate verbal scores) be more likely to select into ECS fields, which are math-intensive, compared to students with requisite math capability but with more balanced achievement profiles (i.e., high math and verbal scores), and would this pattern apply equally to URM males, URM females, non-URM males, and non-URM females? To answer these questions, we first explored the patterns of ECS enrollment based on the intersection of sex and race/ethnicity and compared these patterns against students' likelihood of ECS enrollment when they scored in the same SAT ranges. Next, using an intersectional approach, we examined Virginia public school graduates' college majors in relation to their senior-year SAT scores for URM males and females and non-URM males and females. We hypothesized that students with math-favored, imbalanced achievement would be more likely to select into ECS fields compared to students with balanced achievement profiles. Because the current study was the first to examine whether this pattern would apply equally to URM males, URM females, non-URM males, and non-URM females, this research question is exploratory by necessity. We extend the literature by (1) expanding the imbalance theory to a state population level, compared to a select, academically gifted sample, and (2) applying an intersectional approach to better understand both representation patterns and potential predictors of ECS enrollment. By exploring the choice of college majors—one of the initial steps toward a career in ECS—we can characterize a critical early transition along the school-to-career pathway. Our results provide a more nuanced understanding of how SAT scores may

affect ECS enrollment from an intersectional perspective, and thus can help inform admissions decision-making to diversify and broaden ECS participation from key underrepresented demographics, a key goal of STEM education (National Research Council, 2011).

Methods

We drew our statewide population-level data from the Virginia Longitudinal Data System (VLDS), an automated federated linkage system developed with funds from the U.S. Department of Education that allowed us to combine student-level records from public high schools with records from postsecondary institutions. Virginia Department of Education (VDOE) and the State Council of Higher Education for Virginia (SCHEV) personnel reviewed and approved our data research requests and our university Institutional Review Board approved the study. Records from four databases—K-12 Student Record Collection (SRC), SAT, the National Student Clearinghouse (NSC), and Coursetaking I—were probabilistically matched by the VLDS by unique student, de-identified and made available to the team for download (Jonas et al., 2015; Schroeder, 2012). We created a database of unique students' high school senior year records from 2006 to 2015. These data (i.e., all Virginia public high school graduates from 2006 to 2015, $N=852{,}580$) were reviewed, cleaned, and then joined to address the research questions for this paper.

The final dataset represented a census of all administrative records of students who graduated from a Virginia public high school between 2006 and 2015 who enrolled in a 4-year postsecondary institution (public or private), and who took the SAT—as opposed to the ACT—exams ($N=344{,}803$; see Fig. 1). The dataset consisted of more females than males and was racially/ethnically diverse (36% non-White), similar to Virginia's sex and racial/ethnic makeup in 2010 (51% female and 38% non-White, U.S.). Most of the students (86%) were not economically disadvantaged (see Table 1).

Measures

College major

Students' college major was compiled using records from SCHEV and NSC using the Classification of Instructional Programs codes for Engineering (14, 15) and Computer and Information Science (11). We identified ECS students as those who declared as ECS majors at any time during their postsecondary educations while enrolled at a 4-year public or private postsecondary institution, including students who transferred from a 2-year college to a 4-year college as well as those who only matriculated at a 4-year institution.

Math and verbal SAT scores

SAT verbal and math scores were used to assess academic skills that most U.S. universities use in making enrollment decisions. While evidence suggests that these tests may not accurately reflect ability across all demographic groups—performance gaps on SATs are at least in part attributable to a host of other factors including sex differences in competitive test-taking (e.g., Niederle & Vesterlund, 2010), inequities in access to college preparatory resources, and the ability to take and retake these pay-to-take exams (e.g.,

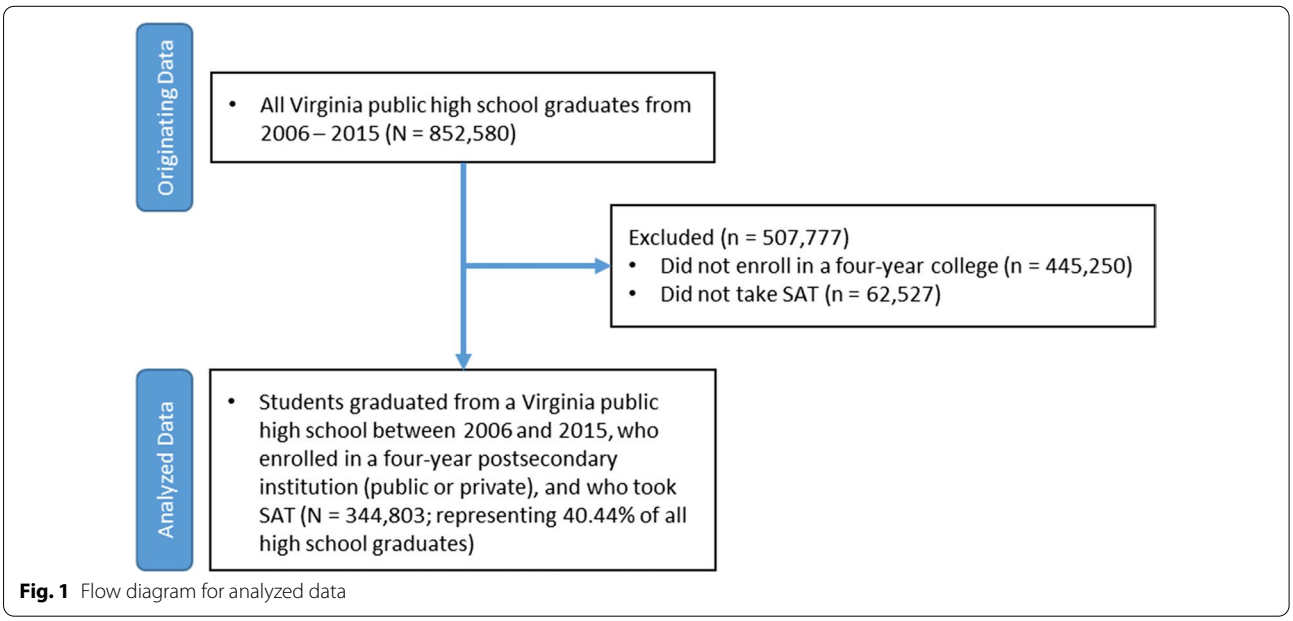

Fig. 1 Flow diagram for analyzed data

Table 1 High school senior year demographic information as percentages of the students

	Percentage of the students (2006–2015, *N* = 344,803)
Sex	
Male	43.87
Female	56.13
Race/ethnicity	
American Indian/Alaska native	0.24
Asian	8.78
Black or African American	18.59
Hispanic	4.73
White	64.49
Native Hawaiian/Other Pacific Islander	0.11
Two or more races	2.47
Unspecified	0.59
Disadvantaged status	
Yes	14.01
No	85.99

Buchmann et al., 2010)—we use them because this is what 4-year colleges use, and to compare our results with prior research (e.g., Wang et al., 2013). Test scores ranged from 200 to 800, the full standardized scale of the test. Consistent with current U.S. college admissions policies, we included students' highest math or verbal score if a student had multiple test scores. Although either the SAT or ACT may be taken by students, the SAT is the much more common standardized test taken by Virginia students. As noted by Cook and Turner's (2019) analysis, only 2.4% of students in the 2014 graduating cohort took only the ACT; like that prior work, and rather than introducing different biases for comparing subject-specific scores across different tests (i.e., particularly since we did not analyze composite scores), we elected to only focus on SAT scores.

Sex and URM status

Parents or students provided sex and race/ethnicity information at high school enrollment, which was recorded in the SRC managed by the VDOE. For this study, we used students' fall semester 12th-grade records. Students' race/ethnicity is recorded in five categories. For this study, non-URM students included White and Asian American students, while all others—Black, Hispanic, or "other", including biracial—were included as URM students.

Economically disadvantaged status

Students were flagged in the VLDS system as economically disadvantaged if they (a) were eligible for free/reduced meals; (b) received Temporary Assistance for Needy Families (TANF); (c) were eligible for Medicaid; or (d) identified as either migrant or experiencing homelessness at any point during the school year (Virginia Department of Education, 2020). Because students' economic status was found to be related to ECS enrollment (Knight et al., 2020), we controlled the economically disadvantaged status in the logistic regression.

Analyses

To explore the patterns of ECS enrollment based on the intersection of sex and race/ethnicity, we divided students into four groups, non-URM female, URM female, non-URM male, and URM male students, and then conducted descriptive analyses. We calculated a representation ratio to better understand each group's representation in ECS compared to their college enrollment:

$$\text{Ratio} = \frac{n \text{ of ECS students in the sex and URM group/total } n \text{ of ECS students}}{n \text{ of college students in the sex and URM group/total } n \text{ of college students}}.$$

A ratio above 1 demonstrates overrepresentation in ECS compared to their 4-year enrollment, while a ratio below 1 indicates underrepresentation in ECS compared to their 4-year enrollment; the smaller the ratio, the less represented in the ECS programs.

To test whether students with math-favored, imbalanced achievement are more likely to declare ECS majors, compared to students with more balanced SAT profiles using an intersectional approach, we conducted two sets of analyses. We first explored the percentage of non-URM female, URM female, non-URM male, and URM male students who enrolled in 4-year postsecondary ECS programs based on their SAT math (from 401 to 800) and verbal (from 501 to 800) score ranges. To best plot these ranges, we further divided math scores into eight equal ranges (50-point spreads) and verbal scores into thirds, yielding eight math and three verbal bands. We calculated bands based on distributional ranges in relation to outcome. The percentage of students enrolling in ECS programs based on math scores was highly skewed, in that relatively few

students ($n = 441$, 0.13%) with scores equal to or below 400 enrolled in ECS programs. Additionally, based on distributions of verbal scores, three equal bands appeared to best represent the data. Groupings with fewer than 10 students were suppressed to minimize the risk of deductive disclosure.

Next, we performed a logistic regression analysis to examine the probability of ECS enrollment predicted by sex, URM status, and math and verbal SAT scores using the entire dataset ($N = 344{,}803$). We scaled SAT math and verbal scores to 30-point intervals by dividing the scores by 30 and rounding them up to the nearest integer so the coefficients were more interpretable. To create interaction terms and render the coefficients more interpretable, we then centered the math and verbal scores to the median scores of all students who majored in ECS at 640 for math and 580 for verbal scores (it is worth noting here that the apparent difference in the median math and verbal SAT scores suggested overall math-favored, imbalance profiles among ECS students). We multiplied (1) sex and URM; (2) sex, math score, and verbal score; and (3) URM, math score, and verbal score, to create interaction terms. We then plotted the estimated probability based on the estimated coefficients (see Table 3) from the logistic regression for the four sex (male = 1, female = 0) and race/ethnicity (non-URM = 1, URM = 0) groups. Given that SAT math and verbal scores were scaled to 30-point intervals and centered, the full range of math scores used for the plot corresponded to the score range of 200 to 800, and the verbal scores used for the plot were 550, 650, and 750.

Results

ECS enrollment patterns by sex and ethnicity

We divided students into four groups: non-URM female, URM female, non-URM male, and URM male groups. Within the four groups, 15.10% of non-URM males and 9.80% of URM males enrolled in ECS programs, as did 3.62% of non-URM females and 2.32% of URM females. As shown in Table 2, non-URM males predominated in ECS programs, comprising more than half of all ECS students (63.74%), while representing a much smaller share of the 4-year college-going population (33.31%), which resulted in a ratio of 1.91. URM males comprised 13.11% of the ECS students, which was also a higher proportional share compared to their share of the 4-year college population (10.56%). The ratio of URM males was 1.24. Thus, relative to themselves, both URM and non-URM males were overrepresented in ECS compared to an aggregate of all majors. In contrast, both URM and non-URM females were underrepresented in ECS compared to the 4-year college population. White and Asian American females (non-URM) comprised 18.58% of ECS students, while their share of the 4-year college enrollment rate was 40.55%, which resulted in a ratio of .46. URM females were the most underrepresented in the ECS programs, comprising 4.57% of ECS majors while representing 15.58% of the 4-year college population, that is, the ratio of URM females was .29.

SAT patterns and ECS enrollment

To examine ECS enrollment as a function of students' SAT profiles, we first conducted descriptive statistics. As shown in Table 2, within each intersectional group,

Table 2 Descriptive statistics

	Non-URM female	URM female	Non-URM male	URM male
ECS enrollment				
n	5055	1244	17,343	3566
% of ECS enrollment	18.58%	4.57%	63.74%	13.11%
% of intersectional group	3.62%	2.32%	15.10%	9.80%
% of all students	1.47%	.36%	5.03%	1.03%
Mean math score (SD)	642.74 (84.26)	557.15 (101.23)	642.23 (783.60)	560.23 (105.08)
Mean verbal score (SD)	609.71 (91.95)	537.41 (101.42)	589.78 (91.66)	524.01 (101.38)
Other enrollment				
n	134,760	52,483	97,519	32,833
% of other enrollment	42.43%	16.53%	30.71%	10.34%
% of intersectional group	96.38%	97.68%	84.90%	90.20%
% of the sample	39.08%	15.22%	28.28%	9.52%
Mean math score (SD)	536.22 (91.47)	457.42 (88.28)	566.80 (95.86)	475.29 (97.79)
Mean verbal score (SD)	548.05 (96.09)	473.28 (93.40)	551.40 (98.47)	470.06 (98.34)

Standard deviations (SD) are in the parentheses. % of ECS enrollment = n/the total number of ECS enrollment students; % of other enrollment = n/the total number of other enrollment students; % of all students = n/the total students ($N = 344{,}803$); % of intersectional group = n/the number of students in the group (non-URM female, URM female, non-URM male, and URM male)

students who declared ECS majors had higher average SAT math and verbal scores compared to students who declared other majors. For students who declared ECS majors, non-URM students showed higher average SAT math and verbal scores than did URM students, while URM males and females, as well as non-URM males and females, had similar math and verbal scores. To further explore the group differences, we then conducted two three-way ANOVAs to examine the interaction effects of sex, URM status, and ECS enrollment as a function of students' SAT math and verbal scores (see the Additional file 1: Table S1 and Figures S1 and S2).

Next, we plotted the percentage of students enrolling in ECS programs as a function of their SAT pattern by group. As seen in Fig. 2, for all groups, higher math scores were associated with higher ECS enrollment. Comparing within the male/female groups, the percentage of URM students enrolling in ECS was similar to,

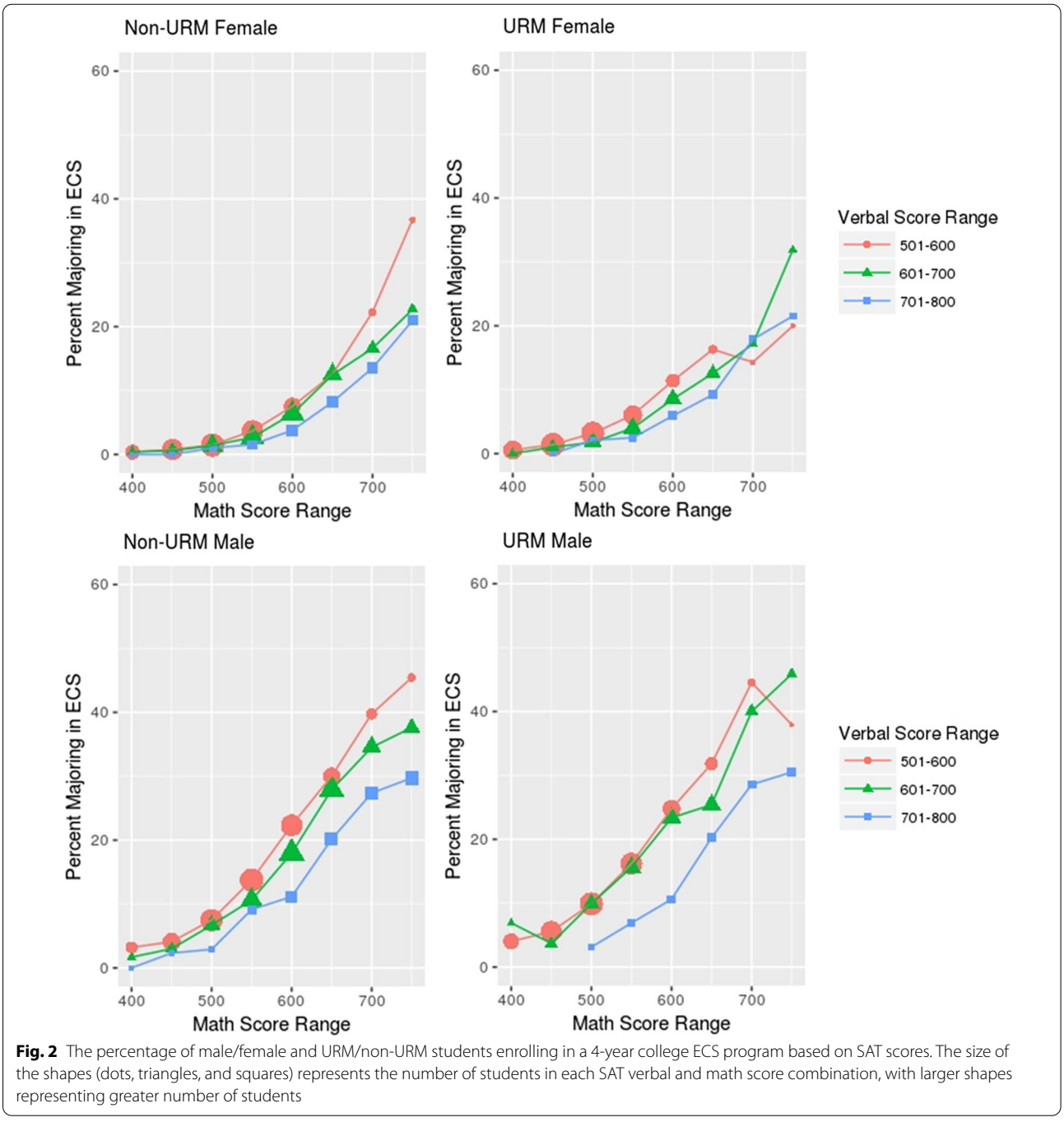

Fig. 2 The percentage of male/female and URM/non-URM students enrolling in a 4-year college ECS program based on SAT scores. The size of the shapes (dots, triangles, and squares) represents the number of students in each SAT verbal and math score combination, with larger shapes representing greater number of students

sometimes even higher than, those of non-URM students when they had the same SAT score range (verbal and math). For all groups, the percentage of students majoring in ECS programs generally decreased as their verbal score range increased within the same math range. However, only for URM females, the percentages of ECS enrollment were higher when they had balanced profiles (high verbal scores matched high math scores) than when they had imbalanced profiles (high math scores, 700–800, but moderate verbal scores, 500–600).

To model the previous results, we conducted a logistic regression analysis to examine the likelihood of student ECS enrollment as a function of the interactions between (1) sex and URM status, (2) sex, math, and verbal SAT scores, using our truncated score bands, as well as (3) URM status, math score, and verbal score (see Table 3). Although the effect size is very small, the odds of disadvantaged students declaring an ECS major were 15% higher than the odds of non-disadvantaged students doing so after controlling for other variables. When scoring 640 on the Math SAT and 580 on the Verbal, the odds of URM males declaring an ECS major were 157% higher than the odds of URM females doing so, and the odds of non-URM female students majoring in an ECS program were 27% lower than the odds of URM female students doing so. The interactions were plotted based on SAT scores, sex, and URM status by calculating the predicted probability based on the model (see Fig. 3 and Additional file 1: Fig. S3). Consistent with Fig. 2, which showed actual data, the probability of students enrolling in ECS majors increased as math scores increased and decreased when the verbal scores increased for each group of students. However, this general pattern was markedly less pronounced in the URM female students as depicted by the narrow gaps between the three verbal score lines in Fig. 3.

Discussion

The goal of the current investigation was to advance research on broadening ECS participation by better understanding who enter the ECS career pipeline through choice of college major, as a function of the relative balance of student math and verbal aptitudes within the context of intersecting sex and racial/ethnic identities. Our findings show that, across one U.S. state and 10 years, while males (URM or non-URM) were substantially more represented than females in ECS programs, with URM females being the least represented in ECS programs, overall *interest* in ECS appeared to be similar, or even higher, proportionally in URM students compared to equally capable non-URM peers. That is, *within each sex*, URM students were as likely, and in cases with high SAT scores, more likely, than non-URM students to major in ECS programs when they had similar SAT profiles. The findings are broadly consistent with Riegle-Crumb and Kings' (2010) finding that when academic preparation is controlled, Black male and female students were more likely to enroll in an engineering or physical science major than White males and females, respectively. Together, our study and theirs underscore the utility of an intersectional approach in highlighting trends that may otherwise go undetected.

The gap between apparent URM ECS interest and representation may be easily explained by the fact that

Table 3 Predicting ECS enrollment from sex, URM status, math and verbal scores

	β	Standard error	Odds ratio	95% CI
Intercept	−2.11*	0.04	0.12	0.11–0.13
Disadvantaged (1 = disadvantaged; 0 = not disadvantaged)	0.14*	0.02	1.15	1.09–1.20
Sex (1 = male; 0 = female)	0.94*	0.04	2.57	2.36–2.79
URM (1 = non-URM; 0 = URM)	−0.31*	0.04	0.73	0.68–0.79
Math score	0.39*	0.01	1.48	1.45–1.50
Verbal score	−0.07*	0.01	0.93	0.92–0.95
Int: Sex × URM	0.23*	0.04	1.26	1.16–1.37
Int: Sex × Math score	−0.12*	0.01	0.89	0.88–0.90
Int: Sex × Verbal score	0.00	0.01	1.00	0.99–1.01
Int: Math score × Verbal score	0.00	0.00	1.00	1.00–1.00
Int: URM × Math score	0.03*	0.01	1.03	1.01–1.05
Int: URM × Verbal score	−0.01	0.01	0.99	0.97–1.00[a]
Int: Sex × Math score × Verbal score	−0.00*	0.00	0.99	0.99–1.00[a]
Int: URM × Math score × Verbal score	−0.01*	0.00	0.99	0.99–0.99

*$p < .001$. The numbers were rounded to 2 decimal points. Int = Interaction term. [a]The number was less than 1.00

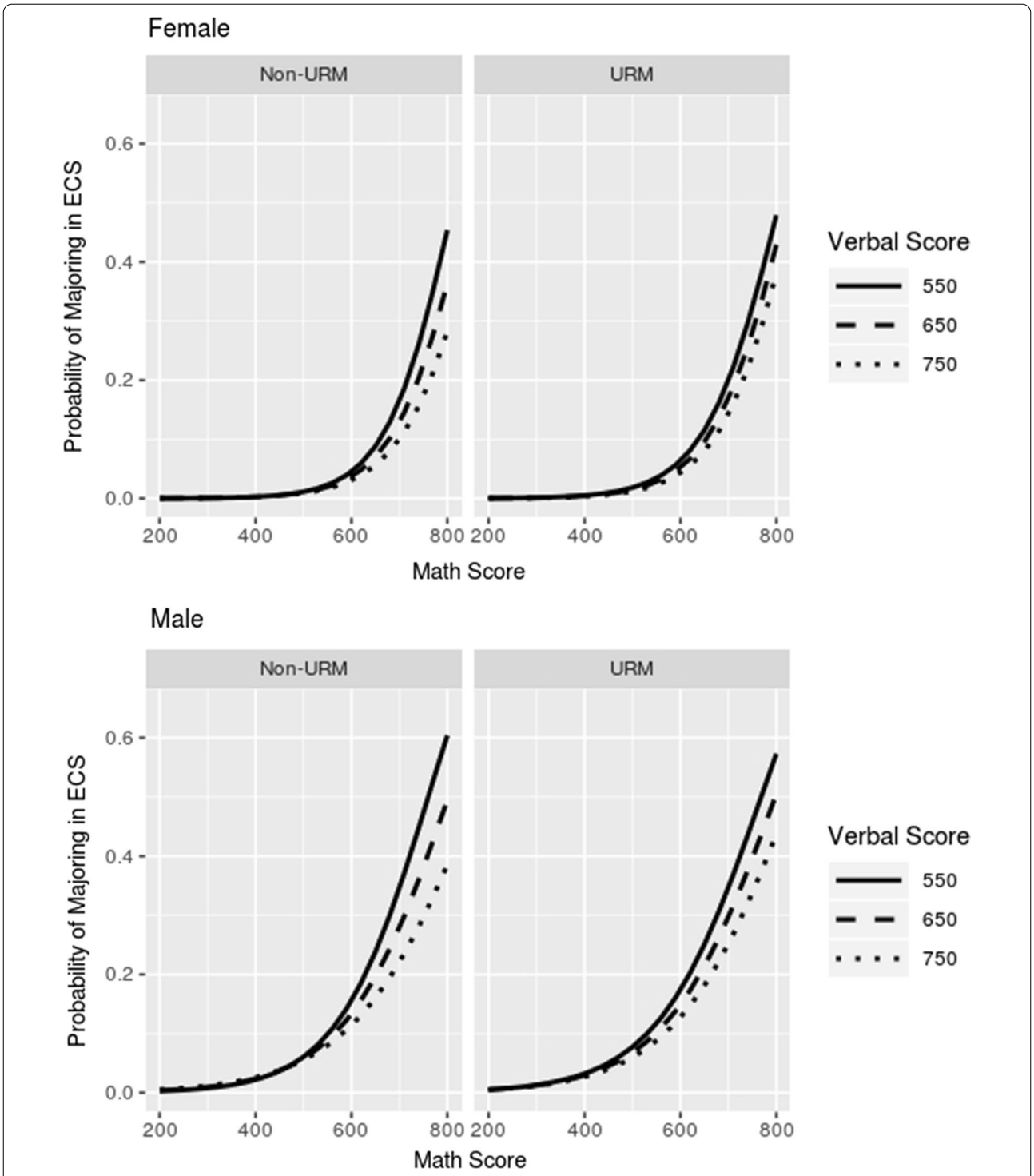

Fig. 3 The probability of male/female and URM/non-URM students enrolling in a 4-year college ECS program based on 12th grade SAT scores. The predicted probability was calculated based on the logistic regression model presented in Table 3

considerably fewer URM students reported high math and verbal SAT scores compared to non-URM students. Within each sex, URM students' average SAT scores were lower than non-URM students' average scores. This SAT score differential may be one driver of racial and ethnic disparity in ECS college majors, if our finding of relatively high ECS interest holds true across 4-year college URM students generally. Reasons why U.S. URM students score lower on average than their college-bound non-URM peers include a host of socioeconomic and sociological factors, including having been more likely to graduate from resource-poorer school districts with less access to advanced math classes (Riegle-Crumb & Grodsky, 2010), teacher perception of math ability implicitly biased in favor of White and male students (Copur-Gencturk et al., 2020) and even that the SAT itself is inherently biased against some subpopulations (Nguyen & Ryan, 2008). It follows that heavy reliance on pre-selected SAT criterion scores for ECS admission likely constitutes a real constraint to broadening participation across URM ethnic groups in the U.S. The COVID pandemic-spurred suspension of using SATs for many college admissions, at least for the 2020–2021 academic year, offers an opportunity to explore this conjecture. Future research should study how this shift in practice might influence equity in college and ECS admissions, while paying attention to student retention and graduation.

We also found, as predicted, that males and non-URM females were less likely to enroll in ECS programs if their SAT profile favored both verbal and math prowess (high balanced profile), compared to students with very high math and lower verbal scores (high math-favored profile). With one important exception, our results are broadly consistent with those of Davison et al. (2014) and Wang et al. (2013). The results in Davison et al. (2014) show that higher SAT math and lower SAT verbal scores were associated with a higher likelihood of majoring in ECS programs. Similarly, Wang et al. (2014) found that adults who had scored very high in both math (mean = 720) and verbal (mean = 696) domains as teenagers were less likely to work in STEM careers by age 33 than those whose very high math scores were (mean = 721) offset by somewhat lower verbal (mean = 655) scores. Consistent with these previous studies' interpretation, it may be that this 10-year dataset of Virginia students who scored high on both math and verbal SAT sections (balanced profile) perceived wider major and career options than their peers who scored high only in the math domain and thus may have been less likely to major in ECS. Bandura's motivational self-efficacy and outcome expectancy theory (Bandura, 1982), particularly applied to career choice (e.g., Social Cognitive Career Theory; Lent et al., 1994; Hackett & Betz, 1981), posits that academic interests and career choices result from repeated, active exposure to and involvement with academic learning, coupled with vicarious learning through role models and feedback, that fosters a sense of competence and efficacy, which in turn fosters academic and career interests. When students feel competent in certain academic areas, they are more likely to pursue them, so math-favored SAT profiles may reflect more narrow student interests, such that these students are more likely to declare as ECS majors. While our results empirically support the imbalance theory—that students with math-favored, imbalanced achievement are more likely to select into ECS fields compared to students with requisite math capability but balanced achievement profiles—our intersectional lens suggests the theory be broadened to include a group membership dimension, as this pattern described mostly male and non-URM female groups.

In contrast, the math-favored imbalance pattern was notably less pronounced for URM females. Singularly in this group, a lower percentage of students who had very high math scores (701 to 800 range) and moderate verbal scores (501 to 600 range; an imbalanced SAT profile) declared ECS majors compared to those with a high balanced profile. URM female students with high verbal scores (601 to 800 range) were more likely to enroll in ECS programs compared to their majority female peers with similar balanced profiles, yet URM females are proportionally underrepresented in earning ECS degrees relative to their composition of the U.S. adult population (National Science Foundation, 2017)—which was consistent with our own finding that only 2.32% of URM female students declared ECS majors. Our results highlight the discrepancy between evident high enthusiasm towards ECS programs (indexed by the fact that these females gravitated toward ECS even when their balanced profiles might provide them with more major choices) and the disproportionately lowest representation of all groups for URM females. This discrepancy is likely due to only a small number of URM females scored in the highest math score range.

A second, not mutually exclusive possibility is that the pattern we report may reflect the results of intensive recruitment efforts. To help diversify ECS program participation, URM female students may be particularly heavily recruited if they meet a certain math score threshold, regardless of the verbal score. Such recruitment could be in the form of financial assistance, internship opportunities, or other high touch recruitment incentives (Chowdhury & Chowdhury, 2007; May & Chubin, 2003). Future research that investigates the extent of, if and in what ways these recruitment strategies are successful with URM females would help explicate

our findings and provide useful information to colleges intent on diversifying ECS.

Considering the intersection of sex and race/ethnicity from both a male and female perspective, URM males and females may face different opportunities and challenges when declaring college majors. It is noteworthy that as a group, unlike URM females, URM males were overrepresented in ECS fields relative to their 4-year college enrollment rates. This finding suggests that URM males may be particularly interested in ECS careers, but that a potent bottleneck in the ECS pipeline lies in their low relative rates of attending 4-year colleges. Reasons are no doubt manifold, but one strong implication of our findings is that doubling down on middle and high school preparation for and recruitment into college for this group is critical (Glessner et al., 2017; Tyson et al., 2007). URM students tend to attend high schools that are under-resourced (Knight et al., 2020), which places URM students at a distinct disadvantage for educational attainment. Finding ways to address the systematic school inequities should go a long way to help increase URM males' 4-year college and ECS participation.

Our results focus on the particular cultural and societally designated sex and race/ethnicity demographic roles of the U.S. in relation to patterns of ECS uptake in college; the particulars, both of who is and isn't proportionally represented in ECS likely varies by country, with differing intersecting group memberships perhaps more salient (such as caste in India; see for example, Gupta, 2019). While our particular results may be specific to the U.S. context, future research might profitably determine if similar patterns exist for select underrepresented groups in other national contexts: namely, that greater interest exists in pursuit of ECS in less well-represented groups under conditions of similar preparation and achievement, and whether and for whom an imbalanced vs a balanced achievement profile predicts ECS enrollment.

Limitations and future directions

The current study aimed to understand sex and racial/ethnic differences in ECS program enrollment based on students' SAT scores, informing ways to broaden diversity in ECS fields. Our study represents results from one U.S. state, so our findings—that a higher percentage of students with math-favored SAT profiles, compared to students with balanced SAT profiles, declared ECS majors for all groups except for URM females—need to be replicated with other states or at a national or even international level. Replication is particularly important because the relatively small size of the URM ECS female group may make the results less robust.

Although we investigated a critical step in the ECS career pathway, major declaration, academic preparedness for college and then retention of ECS students are also important factors, particularly for URM students (Huang et al., 2000). Cultivating the interest, confidence, and preparedness in ECS before college and then tracking postsecondary school and career trajectories represents critical future research that can move the field toward better understanding pivotal points of vulnerability—and intervention opportunities—for groups underrepresented in ECS. In addition, student selection of a college major is a multi-pronged process that involves both self- and admission selection processes. Teasing apart how sex, race/ethnicity, and SAT scores might differentially affect the application and admission processes is beyond the scope of the current study, but we encourage future research to investigate these important research questions using an intersectional approach.

Another limitation of the current study is the lack of a general academic preparation index. Including GPA would have been ideal, but VLDS data stewards advised us against using it, as little consistency existed across school districts in how GPA was reported. Including a reliable GPA indicator would improve future studies of this kind. Clearly, many factors besides academic and particularly mathematical capability influence ECS enrollment, including occupational interests, motivational beliefs, family resources to attend a 4-year college, and other human and social capital (Stoet & Geary, 2018; Wang et al., 2013; Wolniak et al., 2008), and we encourage future studies to investigate the impact of these factors on ECS enrollment.

Finally, group size restrictions prevented us from being able to disaggregate underrepresented groups more granularly. U.S. Black and Hispanic men and women showed quite distinct engineering stay rates compared to one another, as well as to their White counterparts and Asian American men (Tao & McNeely, 2019), highlighting the rationale and need for broad intersectional research. In the U.S., large, diverse states like California, Texas and New York may offer the best opportunities for this degree of disaggregation, given coordinated state educational data systems.

Conclusion

Our findings suggest that an intersectionality lens is useful in delineating ECS enrollment patterns; aggregating males and females of different backgrounds or underrepresented students of both sexes can obscure differential tendencies. It follows then that different recruitment and broadening participation strategies may be needed to attract females, and male and female URM students, into ECS. Additionally, when recruiting students, ECS programs may consider emphasizing verbal contributions to the ECS fields and helping students realize having

balanced SAT profiles is a valued and recognized quality during ECS admissions. At a more basic level, if programs continue to emphasize SAT scores during admissions decisions or if more systemic issues of resource allocation in secondary schools are not addressed, other efforts to broaden participation in ECS programs may well fall short of goals. Our findings that students from underrepresented groups are—with other factors controlled—more likely to declare an ECS major underscores a key strategy for addressing disparities: to increase efforts in middle and high school to prepare and enroll these students in advanced math courses (Davenport et al., 1998, 2013; Lee & Burkham, 2002; Teitelbaum, 2003). Adopting an intersectional framework can help deepen understanding of unique barriers and ways to help target efforts to diversify ECS fields.

Supplementary Information

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Additional file 1. The online supplemental material.

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Author contributions

LT conducted the analyses and wrote the manuscript with IB. TK conducted preliminary analyses and created data tables. DK and JG provided methodological and conceptual input. All authors contributed to the study design. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from the Virginia Longitudinal Data System, which are not publicly available. Requests to access the data should be directed to the Virginia Department of Education and the State Council of Higher Education for Virginia (https://vlds.virginia.gov).

Declarations

Competing interests

The authors declare that they have no competing interests.

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