

**Racial and Ethnic Disparities in Advanced Science and Mathematics Achievement During
Elementary School**

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Abstract

We analyzed a population-based cohort ($N=10,922$) to investigate racial and ethnic disparities in advanced (i.e., above 90th percentile) levels of science and mathematics achievement during elementary school as well as antecedent, opportunity, and propensity factors that explained these disparities. About 13%-15% of White students versus 3%-4% of Black or Hispanic students displayed advanced science or mathematics achievement during kindergarten. The antecedent factor of family socio-economic status and the propensity factors of student science, mathematics, and reading achievement by kindergarten consistently explained whether students displayed advanced science or mathematics achievement during first, second, third, fourth, and fifth grade. These and additional factors substantially or fully explained initially observed disparities between Black or Hispanic and White students in advanced science or mathematics achievement during elementary school. Economic and educational policies designed to increase racial and ethnic representation in STEM college course taking and workforce participation may need to begin by elementary school.

Keywords: science achievement, mathematics achievement, race/ethnicity, opportunity-propensity framework; longitudinal.

Racial and Ethnic Disparities in Advanced Science and Mathematics Achievement During Elementary School

Addressing racial and ethnic under-representation in the science, technology, engineering, and mathematics (STEM) workforce (National Science Foundation, 2021) is a national priority (American Society of Mechanical Engineers, 2021; National Academy of Sciences, Engineering, and Medicine [NASEM], 2011). For example, less than 10% of the U.S. STEM workforce is Black or Hispanic¹ (Funk & Parker, 2018; National Science Foundation [NSF], 2019). White or Asian students are more likely to complete college degrees in STEM (Steenbergen-Hu & Olszewski-Kubilius, 2017). Less than 1% of those with a bachelor's degree in science or engineering are American Indian, Native American, or Pacific Islanders (AINAPI). The contrasting percentages for those who are White are 57% and 64% (NSF, 2021). Racial and ethnic under-representation in the STEM workforce currently constrains the nation's economic competitiveness and scientific innovation (Bell et al., 2019; NASEM, 2011). The earning potential of high-achieving Adults of Color who might otherwise pursue high paying STEM careers is also reduced. High-achieving college Students of Color majoring in STEM report early career earnings that are 26%-40% higher than closely matched counterparts majoring in other fields (Melguizo & Wolniak, 2012).

Very high levels of STEM proficiency during adolescence is strongly related to doctoral degree completion and knowledge production in STEM (Agarwal & Gaule, 2020). For example, each additional point scored by high school students participating in the International Mathematical Olympiad predicts a 1 percentage point increase in the likelihood of a doctoral degree in mathematics, a 2.6 percentage increase in publications, a 4.3 percent increase in

¹ The term Hispanic is used throughout this study rather than Hispanic or other descriptors. This is because Hispanic is the specific terminology used in the ECLS-K: 2011 surveys.

citations, and a .03 percentage point increase in the likelihood of becoming a Fields medalist in analyses controlling for cohort and country fixed effects (Agarwal & Gaule, 2020). Advanced STEM achievement (e.g., performing above the 90th percentile) by elementary school is also predictive of scientific innovation in adulthood, as indicated by being listed as an inventor on a technology patent application (Bell et al., 2019). For example, over 30% of the gap in later patent rates between high- and low-income children is explained by their mathematics achievement in 3rd grade (Bell et al., 2019). Earlier gaps by race and ethnicity in later patent rates are also evident. For example, analyses of life-course data of those who attend New York City schools between 3rd and 8th grade indicated that, among White children, 1.6 out of 1,000 later held patents. The contrasting rates for Black and Hispanic children were .05 and .02, respectively (Bell et al., 2019). These rates would have been expected to increase to .06 and .03 for Black and Hispanic children (i.e., percentage changes of 20% and 50%) if they displayed the same mathematics achievement as White children (Bell et al., 2019). However, to what extent Black, Hispanic, or AINAPI students in the U.S. are already less likely to display advanced STEM achievement during elementary school is currently unknown (Joseph et al., 2017; Rambo-Hernandez et al., 2019).

Understanding and addressing racial and ethnic disparities in advanced STEM achievement during the early school years is necessary to ensure equitable educational systems as well as the nation's scientific innovation and economic competitiveness. For instance, Black and Hispanic families often lack access to private tutoring or other supports and instead rely on schools to develop their children's talents (Plucker & Peters, 2016). Interest in STEM typically declines by middle school as students begin viewing scientists as stereotypically White (Hachey, 2020; Wong, 2015). Non-White students are less likely to report science-related career

aspirations as they age (Sheldrake, 2018). Social support from teachers or friends for a student's STEM interests also declines after elementary school (Rice et al., 2013). Middle school STEM achievement fully explains racial and ethnic disparities in advanced high school STEM coursework (Ballón, 2008) as well as predicts persistently held STEM career aspirations (Mau, 2003) and STEM college degree completion (Le & Robbins, 2016). Establishing the size and stability of racial and ethnic disparities in advanced STEM achievement during elementary school as well as explanatory factors of these disparities would inform talent development efforts by an early developmental period when academic skills, interests, and feelings of efficacy towards STEM may be especially modifiable (Hachey, 2020; Morgan et al., 2016; Penner & Paret, 2008; Pringle et al., 2012).

Prior Work Examining Racial and Ethnic Disparities in Advanced STEM Achievement

Achievement disparities in STEM occur by elementary school (Fryer & Levitt, 2004; Henry et al., 2020; Morgan et al., 2016; Navarro et al., 2012; Reardon & Galindo, 2009; Von Hippel et al., 2018). Nationally representative but cross-sectional data from the National Assessment of Educational Progress (NAEP) indicate that large racial and ethnic disparities in advanced science or mathematics achievement also occur by elementary school (NAEP, 2015). Racial and ethnic disparities in advanced STEM achievement are increasing in the United States (Plucker et al., 2013; Rambo-Hernandez et al., 2019). Black and Hispanic students are more likely to display lower achievement growth among those who are academically advanced (Wai & Allen, 2019). Analyses of a large sample from 35 states indicate that disparities in advanced mathematics achievement between students who are White or Asian and those who are Black or Hispanic grow in size across the upper elementary grades (Rambo-Hernandez et al., 2019).

Analyses of state-level administrative data indicate that racial and ethnic disparities in advanced mathematics achievement are already large by third grade (Clotfelter et al., 2009).

Yet the field's understanding specifically of racial and ethnic disparities in advanced STEM achievement during elementary school is currently limited. Relatively few studies of advanced STEM achievement have been conducted, particularly those using elementary school samples and longitudinal designs (Clotfelter et al., 2009; Davis-Kean & Jager, 2014; Gandara, 2005; Rambo-Hernandez et al., 2019). Of these, only two studies have examined racial and ethnic disparities in advanced STEM achievement as early as kindergarten in analyses of nationally representative data (Davis-Kean & Jager, 2014; Gandara, 2005). Neither study reported on explanatory factors for these disparities in adjusted analyses. Most studies examining advanced STEM achievement instead have analyzed samples of middle or high school students (e.g., Kotok, 2017; Lubinski et al., 2014; McCoach & Siegle, 2003) or focused on gender disparities (e.g., Penner & Paret, 2008; Robinson & Lubinski, 2011). For example, one such dataset, the NAEP, only begins to academically assess students in fourth grade. The available longitudinal studies analyzing samples of elementary students often report on achievement disparities based on average performance (Freyer & Levitt, 2004; Kuhfeld et al., 2020; Morgan et al., 2016; Quinn & Cooc, 2015). Yet STEM workforce under-representation is most likely explained by achievement disparities at the upper extreme end of the distribution, and the explanatory factors for disparities in advanced achievement may differ than those for average achievement (Penner & Paret, 2008).

Adjusted analyses investigating whether and to what extent racial and ethnic disparities in advanced science and mathematics achievement begin to occur before the upper elementary grades would help inform targets of educational policies and practices designed to address these

disparities. For example, universal screening for advanced science and mathematics achievement has been suggested as one way to better identify and support talented Black, Hispanic, and AINAPI students (Matthews & Rhodes, 2020; Plucker & Peters, 2016). This is because elementary school teachers may be less likely to recognize academically advanced Students of Color, resulting in a lower access to enrichment activities and supports that might assist their talent development (Grissom & Redding, 2016; Irizarry, 2015). Use of universal screening using standardized measures has been shown to result in much greater likelihood of participation by racially and ethnically diverse elementary students in enrichment programs (Card & Giuliano, 2016), resulting in greater achievement growth by these students (Card & Giuliano, 2015). However, the timing of universal screening and talent supports has been unclear due to the lack of studies examining the early onset of racial and ethnic disparities in advanced science and mathematics achievement. Adjusted analyses also would help clarify factors that may be relatively more important in explaining racial and ethnic disparities in advanced STEM achievement and so might be targeted in through economic and educational policies and practices (Keith, 2019).

Theoretical Framework for Understanding Racial and Ethnic Disparities in Advanced STEM Achievement During Elementary School

An antecedent-opportunity-propensity framework is a well-validated theory of achievement growth (Byrnes, 2020) hypothesizing that a relatively small set of student, family, and school factors explain racial and ethnic disparities in STEM achievement (Byrnes & Miller, 2007; Byrnes & Wasik, 2009; Wang et al., 2013). Antecedent factors help to explain why some students experience greater opportunities to learn including in their homes and schools (Byrnes & Miller-Cotto, 2016). Antecedent factors include a family's socioeconomic status, the language

spoken in the home, and the student's disability status (Byrnes, 2020; Byrnes & Miller-Cotto, 2016; Curran, 2017; Ribner et al., 2019). Because of historically racialized policies and practices as well as ongoing residential and community segregation, Black, Hispanic, and AINAPI students are more likely to experience concentrated poverty, which results in fewer learning opportunities and so racial and ethnic achievement disparities during school (Reardon et al., 2021). About 30% of Black, 24% of Hispanic, and 29% of American Indian or Alaskan Native, students experience poverty in the U.S. in contrast to 9% of White students (Children's Defense Fund, 2020). The greater likelihood of experiencing poverty also disproportionately exposes Black, Hispanic, and AINAPI children to preterm birth, lead, pollutants, and other gestational and environmental factors that increase the risks for disabilities and other health conditions (Mehta et al., 2013; Morgan et al., 2015; Turney, 2020). Being raised in an economically disadvantaged home and having a disability are associated with relatively lower academic achievement (Curran, 2017; NAEP, 2020; Saçkes et al., 2013). Hispanic students are more likely to grow up in homes where a language other than English is primarily spoken (U.S. Department of Education, 2020). Being an emergent bilingual is also associated with relatively lower academic achievement in unadjusted analyses (NAEP, 2020).

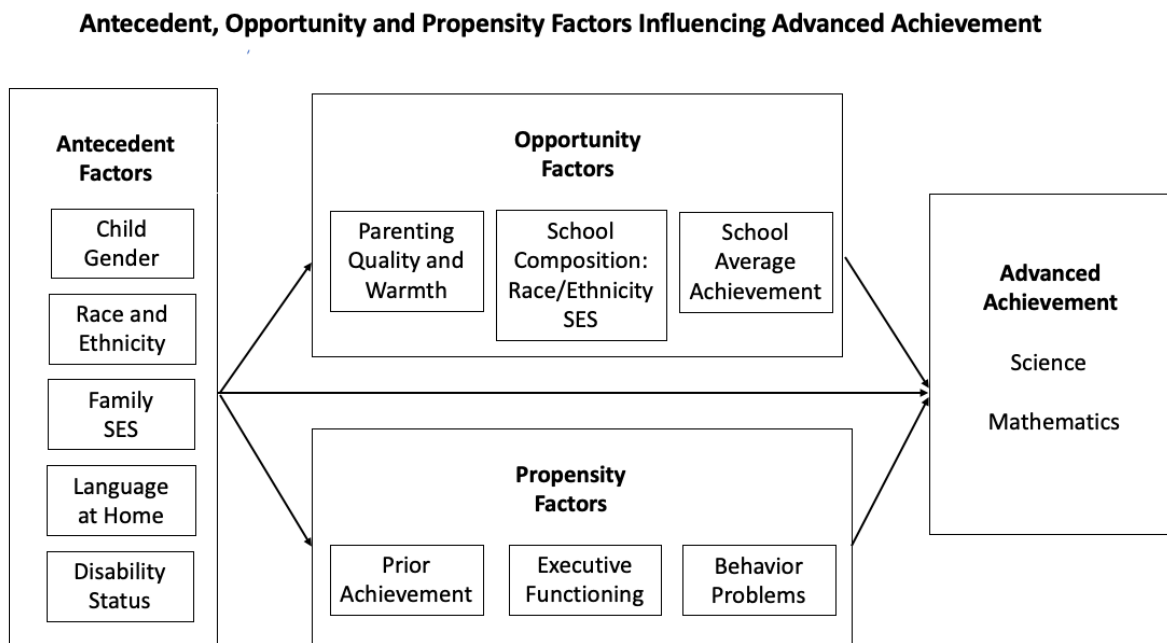
Opportunity factors are defined as aspects of learning contexts in homes and schools that facilitate a student's skills acquisition (Byrnes, 2020). Opportunity factors include parenting quality and the school's economic and racial or ethnic composition (Bae & Lai, 2020; Lewis & Farkas, 2017; Rambo-Hernandez et al., 2019). Black, Hispanic, and AINAPI students are more likely to attend racially segregated and economically disadvantaged schools where fewer resources and professional training opportunities are available to teachers, paraprofessionals, and

administrators as well as where greater staff turnover occurs (Lankford et al., 2002; Sorensen & Ladd, 2020).

Propensity factors are the student's own characteristics that facilitate skill acquisition and maximize the ability to benefit from opportunities to learn. Propensity factors include the student's prior achievement, behavior, and executive functioning (Hoard et al., 2008; Miller-Cotto & Byrnes, 2020; Morgan et al., 2016; Morgan et al., 2019). Because of a greater likelihood of experiencing economic disadvantage, Black, Hispanic, and AINAPI students are more likely to enter schools already displaying lower levels of science or mathematics achievement,

Figure 1:

Conceptual Model of the Study's Antecedent-Opportunity-Propensity Framework



Note. Adapted from Byrnes and Miller (2007)

behavior, or executive functioning (Burchinal et al., 2011; Fryer & Levitt, 2004; Fryer & Levitt, 2013; Morgan et al., 2016; Quinn & Cooc, 2015). Among antecedent, opportunity, and

propensity factors, propensity factors most strongly predict student achievement (Byrnes, 2020; Lewis & Farkas, 2017; Morgan et al., 2016). Antecedent factors lead to opportunity and propensity factors, which then contribute to student achievement (Byrnes & Miller, 2007). Antecedent and opportunity factors can be addressed by economic and educational policies. Propensity factors can be addressed by preschool-and school-based interventions (Ribner et al., 2019). Figure 1 displays a conceptual model of the study's antecedent-opportunity-propensity framework.

Whether antecedent, opportunity, and propensity factors specifically explain racial and ethnic disparities in advanced science and mathematics achievement during elementary school is currently unclear. The few large-scale studies examining racial and ethnic disparities in advanced STEM achievement have been unable to include propensity factors (e.g., prior science, mathematics, or reading achievement, executive functioning) when examining racial and ethnic disparities in advanced STEM achievement (Clotfelter et al., 2009; Gandara, 2005; Rambo-Hernandez et al., 2019). Available work examining gaps in advanced STEM achievement has been descriptive (Clotfelter et al., 2009; Davis-Kean & Jager, 2014; Gandara, 2005) or limited to examining school- instead of student-level factors as risk and protective factors (Rambo-Hernandez et al., 2019). Although racial and ethnic gaps in advanced achievement are increasing in size in the U.S., explanatory factors of these gaps are not well understood (Rambo-Hernandez et al., 2019). Identifying the antecedent, opportunity, and propensity factors that explain racial and ethnic disparities in advanced STEM achievement during elementary school would clarify potential targets of economic and educational policies as well as of early interventions designed to support the STEM achievement of talented Black, Hispanic, and AINAPI students at an especially important developmental time period. The population of talented Black, Hispanic, and

AINAPI students is currently understudied (Irizarry, 2015; Plucker & Peters, 2016; Rambo-Hernandez et al., 2019).

Study's Purpose, Research Questions, and Hypotheses

We investigated racial and ethnic disparities in advanced science and mathematics achievement during elementary school. We were particularly interested in examining the early onset and relative stability of these disparities as well as the antecedent, opportunity, and propensity factors that might explain why Black, Hispanic, or AINAPI students are less likely to display advanced science or mathematics achievement during elementary school. We investigated the following research questions (RQs):

1. Are Black, Hispanic, or AINAPI students less likely than White students to display advanced science or mathematics achievement during elementary school? If so, how large are the observed gaps?
2. Do antecedent, opportunity, and propensity factors explain the lower likelihoods that Black, Hispanic, or AINAPI students display advanced science or mathematics achievement during elementary school?

To investigate these research questions, we evaluated the following two directional hypotheses:

1. Based on prior work examining the early onset and stability of racial or ethnic achievement disparities (e.g., Morgan et al., 2016; Von Hippel et al., 2018), we hypothesized that Black, Hispanic, or AINAPI students would be less likely than White students to display advanced levels of science or mathematics achievement by the end of kindergarten. We then expected these disparities to continue to occur during the subsequent elementary grades (Freyer & Levitt, 2004; Rambo-Hernandez et al., 2019; Von Hippel et al., 2018). We hypothesized that,

in unadjusted analyses, Black, Hispanic, or AINAPI students would be less likely than White students to display advanced science or mathematics achievement during elementary school.

We expected the observed differences to be large (Morgan et al., 2016; Plucker & Peters, 2016; Rambo-Hernandez et al., 2019).

2. Consistent with prior work using the antecedent-opportunity-propensity framework (Byrnes, 2020; Lewis & Farkas, 2017), we further hypothesized that the study's explanatory factors, particularly the family's socio-economic resources and the student's propensities for acquiring advanced levels of science or mathematics skills (e.g., prior achievement, executive functioning) by the end of kindergarten, would substantially or fully explain racial and ethnic disparities in advanced science and mathematics achievement by the end of first, second, third, fourth, and fifth grade.

Methods

Database, Design, and Analytical Sample

We analyzed the public-use version of the nationally representative Early Childhood Longitudinal Study, Kindergarten Class of 2010-11 (ECLS-K: 2011) dataset. The ECLS-K: 2011 is a population-based cohort followed from the fall of kindergarten to the spring of fifth grade. The U.S. Department of Education's National Center for Education Statistics (NCES) maintains the ECLS-K: 2011. Data were collected in the falls and the springs of kindergarten, first grade, and second grade, and then the springs of third, fourth, and fifth grade.

We used the NCES-provided sampling weight $w12p0$, which is a child base weight adjusted for nonresponse associated with both fall and spring kindergarten parent interviews. We used the $w12p0$ weight because most cases that had parent data at both rounds also had child assessment data (Tourangeau et al., 2019). We used multiple imputation (MI) to account for

missing values. Use of MI adjusts for attrition bias more effectively than using attrition weights (Davis-Kean, 2015). MI performs well with up to 50% missing observations (Allison, 2002). We multiply imputed 50 datasets using Stata's *mi impute* command, separately for each regression type.

In the ECLS-K: 2011, students were clustered within schools in our data. We used both student- and school-level variables as predictors. To adjust for clustering, researchers might use hierarchical linear models (HLM) when analyzing the data. However, an alternative method known as cluster-robust standard errors (as well as empirical standard error or sandwich estimators), adjusts the standard errors of the regression coefficients equally well for clustering. This method, which is typically used by biomedical researchers, epidemiologists, and economists, has some advantages over HLM and is at least equally appropriate as HLM for estimating unbiased standard errors from clustered data (McNeish et al., 2017). In the Results section, we present these cluster-robust standard errors calculated by Stata using the school identification number at the spring of kindergarten. Our weighted analytic sample ($N=10,922$) represents estimates of the population of U.S. children who began kindergarten in 2010-2011. The study's explanatory variables of antecedent, opportunity, and propensity factors were measured in the fall or spring of kindergarten. We used these factors to explain the study's criterion variables of the likelihoods of advanced science or mathematics achievement during first, second, third, fourth, or fifth grade in analyses using autoregressive controls.

Advanced Science or Mathematics Achievement

We operationalized advanced science or mathematics achievement as science or mathematics achievement above the 90th percentile of the total test score distribution, separately at each surveyed grade. For example, students who displayed science achievement above the 90th

percentile on the ECLS-K: 2011 measure of general science achievement in the spring of third grade were identified as displaying advanced science achievement in third grade. Using achievement above the 90% percentile as an indicator of advanced STEM achievement is consistent with prior work (Bell et al., 2019; Plucker et al., 2010; Rambo-Hernandez et al., 2019; Zhou et al., 2017). As detailed below, we also used a more liberal cut off of achievement above the 75th percentile and a more conservative cut off of the 95th percentile as robustness checks.

Measurement

Measures of Antecedent Factors

Student and Family Socio-demographic Characteristics. *Gender (dichotomous variable)* was collected from schools during the sampling process and fall kindergarten parent interview and then confirmed by parents in the spring kindergarten. We used male as the reference group. *Student race and ethnicity (category variable)* were surveyed during the parent interviews. Possible responses included White, non-Hispanic; Black/African American, non-Hispanic; Hispanic, race specified; Hispanic, no race specified; Asian, non-Hispanic; Native Hawaiian or Other Pacific Islander, non-Hispanic; American Indian or Alaska Native, non-Hispanic; and more than one race, non-Hispanic. We combined Hispanic, race specified and Hispanic, no race specified into one Hispanic group. We combined Native Hawaiian or Other Pacific Islander, non-Hispanic and American Indian or Alaska Native, non-Hispanic into an AINAPI group. Our analytical racial/ethnic categories were White, Black/African American, Hispanic, Asian, more than one race, and AINAPI. White students were the reference group.² *Student primary home language (dichotomous variable).* Parents were asked whether a language

² We use White students as the study's racial reference group because White students are the largest single racial or ethnic group attending U.S. schools (National Center for Educational Statistics, 2021) as well as the largest single racial or ethnic group of U.S. adults pursuing graduate STEM degrees (NSF, 2021).

other than English was regularly spoken in the home during fall and spring kindergarten.

Reference group responses indicated that English was regularly spoken in the home or that English and another language were equally used. *Household socioeconomic status (SES, continuous variable)* was a composite variable using data from parental interviews in the fall or spring kindergarten on each parent's or guardian's occupation and educational level as well as the family's household income (Tourangeau et al., 2015). We standardized family SES and all continuous variables in the analyses.

Disability status (dichotomous variable) was indicated by whether students had a disability diagnosed by a professional. Parents were asked questions about their child's development (i.e., ability to be independent and take care of himself or herself, ability to pay attention and learn, overall activity level, overall behavior and ability to relate to adults and children, emotional or psychological difficulties, ability to communicate, difficulty in hearing and understanding speech, and eyesight) in the spring kindergarten. Parents who indicated that the child had developmental delays were then asked follow-up questions including whether an evaluation by a professional had occurred, whether a diagnosis of a problem had been obtained, and whether participation in therapy services or special need programming was occurring currently or had occurred in the past. The composite variable was coded "1" if the parent answered "yes" to at least one of the follow-up questions or specified any specific diagnoses. (Excluded responses included a diagnosis of nearsightedness/myopia, farsightedness/hyperopia, color blindness/deficiency, and astigmatism in the case of the vision diagnosis, as well as external ear canal ear wax in the case of hearing diagnosis). We conservatively coded the composite variable as "0" if the child had a diagnosis but the specific diagnosis was not reported (i.e., responses

including refused, “don’t know,” or not ascertained). Students without disabilities were the reference group.

Measures of Opportunity Factors

Parenting Quality. We included five measures of parenting quality (continuous variables) as surveyed in the fall or spring of kindergarten. *Cognitive stimulation* ($\alpha=0.72$) was a standardized sum of nine questions answered in the fall of kindergarten indicating how often the parent engaged in activities with their child in a typical week. These activities included telling stories, singing songs, doing arts and crafting, playing games or puzzles, doing science projects or talking about nature, playing construction toys, doing household chores, exercising or playing sports, and practicing reading, writing or working with numbers. *Emergent literacy* ($\alpha=0.57$) was a standardized composite score of five items related to literacy activities. The first three items assessed the frequency of parents engaging in book reading and picture book reading with the child as well as child reading outside school. The last two reported the number of books their child owned and how long the parent spent on reading to their child. We added standardized scores of the first three items and the last two items to get the standardized composite score. *Parent-child activities* ($\alpha=0.65$) was a standardized composite score of six items assessing whether the parent had participated in the activities with their child over the past month including visiting a library, a bookstore, an art gallery, a concert, a zoo, or a sport event, as well as twelve questions regarding whether their child ever engaged in out-school activities including academic activities (e.g., tutoring or math lab), dance/music/drama/art/crafts lessons, organized athletics/clubs/preforming arts programs, and instructions (non-English language, religious, and volunteer work). *Parental warmth* ($\alpha=0.65$) was a measure of four items asking parent to self-assess their relationship with their child by showing love, expressing affection, spending close

time together, and child-parent closeness. These four items were originally scaled 1 to 4 indicating “completely true” to “not at all true.” We used reversed coding so that higher scores indicated greater parental warmth. *Family TV rules* ($\alpha=0.52$) was a standardized composite of three parent-reported binary questions indicating whether there were family rules about: (a) allowable TV programs; (b) how many hours of TV the child could watch; and (c) how early or late the child watched television. Parents voluntarily self-reported information on their parenting practices. Similar groupings of these items have been used in prior work investigating parental literary activities (e.g., Byrnes et al., 2019), cognitive stimulation (e.g., Slicker et al., 2021), parent-child activities (e.g., Kim, 2021), and parental warmth (e.g., Ogg & Anthony, 2020).

School Characteristics. School opportunity factors as continuous variables included the percent of students receiving free school lunch and reduced-price school lunch, the percent of non-White students, and averaged science and mathematics achievement in the spring of kindergarten.

Measures of Propensity Factors

Science, Mathematics, and Reading Achievement (continuous variables). Trained field staff individually assessed a student’s science, mathematics and reading achievement using untimed and item response theory (IRT) scaled measures. Measure administration included a two-stage assessment process. The first stage was a routing section. This included items of varying degrees of difficulty that, depending on the student’s performance, was followed with one of three second-stage assessments (i.e., additional low-, middle-, or high- difficulty items) indicated by the student’s prior routing stage’s performance. The science achievement measure was based on the 2011 NAEP Science framework and the curriculum standards of Arizona, California, Florida, New Mexico, Texas, and Virginia. The mathematics achievement was

developed based on 2005 NAEP Mathematics Framework and curriculum standards of California, New Jersey, Tennessee, Texas, and Virginia. The reading achievement measure was based on the 2009 NAEP Reading Framework and the curriculum standards of Texas, California, New Jersey, Florida, and Virginia.

The science achievement measure was designed to assess a student's understanding about the physical, life, and Earth and space sciences as well as scientific inquiry. The mathematics achievement measure was designed to assess a student's conceptual knowledge, procedural knowledge, and problem solving. The mathematics achievement measure included items on number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and patterns, algebra, and functions. The reading achievement measure was designed to assess basic reading skills (e.g., print familiarity), vocabulary, and reading comprehension. The reliabilities for the ECLS-K: 2011's science and mathematics assessments were relatively high across kindergarten to fifth grade. The science and mathematics reliability coefficients ranged from 0.73 to 0.86 and 0.93 to 0.94, respectively, across kindergarten to fifth grade. The reading reliability coefficient was 0.95 in the spring of kindergarten.

Executive Functioning. We included assessments of cognitive flexibility, working memory, and inhibitory control as three continuous variables indicating executive functioning. *Cognitive flexibility* was individually assessed by the Dimensional Change Card Sort (DCCS; Zelazo, 2006). Students were asked to sort 22 different picture cards based on different rules (i.e., sorting cards based on color, shape, and border). Each card had a picture of either a red rabbit or a blue boat. Students sorted the cards by color and then by shape. Four of six cards had to be correctly sorted by shape to proceed to sorting by border. Students who proceeded were

asked to sort cards with black borders by color and cards without black borders by shape. A total score was developed by combining scores of all the three tasks. The DCCS displays strong test-retest reliability (e.g., 0.90-0.94; Beck et al., 2011).

Working memory was individually assessed using the Numbers Reversed subtest of the Woodcock-Johnson III Tests of Cognitive Abilities (Woodcock et al., 2001). The Numbers Reversed task has strong test-retest reliability (e.g., 0.69-0.87; Vought, 2011). Students repeated sets of orally presented single-digit numbers in reverse order. Students were first given 5 two-digit sequences. For example, if presented with the sequence “3, 5”, a student would be expected to respond with “5, 3.” The assessment continued until the maximum of eight-number sequences was completed or three consecutive incorrect responses were given. We used the *W* scores as recommended by the measure’s publishers (Mather & Woodcock, 2001). The *W* scale is a standardized scale with a *M* of 500 and a *SD* of 100.

Inhibitory control was individually rated by teachers using the Children’s Behavior Questionnaire (Putnam & Rothbart, 2006). Teacher ratings are a valid measure of inhibitory control (Allan et al., 2014). During the spring of kindergarten, teachers rated how often individual students demonstrated social behaviors related to attention and inhibitory control. The inhibitory control subscale consisted of six items assessing how students reacted to different situations in the past 6 months including whether students were easily distracted or could be stopped from doing something as instructed. Teachers used a 7-point rating scale from “extremely untrue” to “extremely true.” The reliability coefficient for the inhibitory control scale was 0.87 (Tourangeau et al., 2019).

Behavioral Functioning (continuous variables). Teachers rated how often their students exhibited externalizing or internalizing problem behaviors during the spring of kindergarten

using a modified version of the Social Skills Rating System (Gresham & Elliott, 1990). The Social Skills Rating System displays evidence of internal consistency including over time, interrater reliability, construct- as well as criterion-related validity, and factor invariance across White and non-White elementary students (Elliott et al., 1988; Ogden, 2010; Walthall et al., 2005). The *Externalizing Problem Behaviors* subscale consisted of five items (i.e., arguing, fighting, acting impulsively, getting angry, disturbing activities). The *Internalizing Problem Behaviors* subscale consisted of four items (i.e., is the child lonely, sad, anxious, or displayed low self-esteem). Problem behavior frequency was rated using a four-point response scale ranging from “never” to “very often.” Higher scores indicated that the behavior occurred more frequently. Internal consistency reliability coefficients for the externalizing and internalizing problem behaviors scales were reported to be 0.89 and 0.78, respectively (Tourangeau et al., 2019).

Statistical Analyses

To examine RQ 1, we examined the absolute number and relative percentages of students by race or ethnicity who displayed advanced science or mathematics achievement in kindergarten as well as in first, second, third, fourth, and fifth grade. We conducted proportion tests across racial or ethnicity groups (using White, non-Hispanic students as reference group) and applied the Benjamini-Hochberg procedure to avoid potential Type I errors for multiple hypotheses testing (Benjamini & Hochberg, 1995; Chen et al., 2017). To examine RQ 2, we estimated logistic regression models estimated separately for each grade level. We estimated two models for each elementary grade. Model 1 was an unadjusted model including only the antecedent factor of race or ethnicity. Model 2 was a fully adjusted model that simultaneously included antecedent, opportunity, and propensity factors measured by the end of kindergarten.

We also controlled for the propensity factors of science and mathematics achievement by the end of kindergarten to better estimate the independent effects of the study's other explanatory factors (VanderWeele, 2020).

The logistic regression models were represented by equations (1) and (2) below, where the log odds of achieving advanced achievement, $\log \left(\frac{\pi}{1-\pi} \right)$, is modelled as a linear function of the study's explanatory factors. Equation (1) included only a set of race/ethnicity dummy variables (with White students as the reference category) as predictors. Equation (2) additionally included a set of antecedent (e.g., home language, family SES, disability status), opportunity (i.e., parenting quality measures, school compositional measures), and propensity factors (e.g., academic and behavioral functioning) as additional explanatory factors. Log odds (or logit) coefficients obtained from the estimated function were transformed into odds ratios by exponentiating the coefficients, $\exp(\beta)$, to aid in interpreting the results.

$$(1) \log \left(\frac{\pi}{1-\pi} \right) = \beta_0 + \beta_1 \text{Race}_1$$

$$(2) \log \left(\frac{\pi}{1-\pi} \right) = \beta_0 + \beta_1 \text{Race}_1 + \beta_2 \text{Antecedent}_2 + \beta_3 \text{Opportunity}_3 + \beta_4 \text{Propensity}_4$$

Robustness Checks

We conducted robustness checks using other operationalizations of advanced science or mathematics achievement. First, we used a more liberal 75th percentile cut off as well as a more conservative 95th percentile cut off (see Supplemental Tables S6 to S9). Second, we operationalized consistently advanced achievement as being in the highest 10% of the averaged science or mathematics achievement scores across first to fifth grade (see Supplemental Tables S10 and S11). Third, we examined the relative consistency of displaying advanced science or mathematics achievement using count variables of the number of times students displayed

advanced science or mathematics achievement using negative binomial regression models (see Supplemental Tables S12 to S15). The results from these robustness checks were consistent with the study's main findings. In the supplemental analyses, we also report the forest plot of estimated odds ratios of race/ethnicity across grades with 95% confidence intervals to visualize the trend of racial/ethnic gaps in advanced achievement over time (see Figure S1 to Figure S4). The online supplement also includes the descriptive statistics for predictors (weighted mean or percentage, before and after multiple imputation), a correlation matrix, the robustness checks, and analytic syntax.

Results

Are Black, Hispanic or AINAPI Students Less Likely to Display Advanced Science or Mathematics Achievement During Elementary School?

Science Achievement

Table 1 displays the number and percentage of students by race or ethnicity who displayed advanced science achievement during each elementary grade. Black or Hispanic students were far less likely than White students to display advanced science achievement in kindergarten. Specifically, 3% and 4% of Black and Hispanic versus about 16% of White students ($p < .001$) displayed advanced science achievement. Statistically and practically significant disparities between Black, Hispanic, and White students in advanced science achievement were then evident in each of the subsequent elementary grades. About 5% of students who are AINAPI displayed advanced science achievement by kindergarten. This percentage was 4% by fifth grade. Asian students were initially less likely than White students to display advanced science achievement in kindergarten (i.e., 7% versus 16%, respectively). By

fifth grade, however, Asian students were more likely than White students to display advanced science achievement (i.e., 16% versus 13%, respectively).

Mathematics Achievement

Table 2 displays the number and percentage of students by race or ethnicity who displayed advanced mathematics achievement during each elementary grade. Racial and ethnic disparities in advanced mathematics achievement were also large by the end of kindergarten. About 4% of Black or Hispanic students and about 13% of White students ($p < .001$) displayed advanced mathematics achievement. Large disparities between Black, Hispanic, and White students also occurred in first, second, third, fourth, and fifth grade. At the end of fifth grade, about 2% of Black students and 3% of Hispanic students displayed advanced mathematics achievement. About 13% of White students and 22% of Asian students did so. American Indian or Native American students were also consistently less likely to display advanced mathematics achievement than White students. The percentages of AINAPI students displaying advanced mathematics achievement during elementary school ranged from 5% to 7%.

Do Antecedent, Opportunity, and Propensity Factors Explain Racial and Ethnic Disparities in Advanced Science or Mathematics Achievement During Elementary School?

Science Achievement

Table 3 displays results from the logistic regression modeling of explanatory factors of racial and ethnic disparities in advanced science achievement at the end of first, second, third, fourth, or fifth grade using antecedent, opportunity, and propensity factors measured by the end of kindergarten. Model 1's unadjusted estimates repeatedly indicated large racial and ethnic disparities in advanced science achievement during each of the examined elementary grades. Black and Hispanic students were significantly less likely than their White peers to have

advanced science achievement across all grades, with the unadjusted odds ratios ranging from 0.17 to 0.23 and 0.26 to 0.32 ($p < .001$), respectively. AINAPI students were initially significantly less likely to display advanced science achievement in the first and third grade but this disparity was not statistically significant following a correction for multiple comparisons.

Model 2's antecedent, opportunity, and propensity factors significantly explained disparities in advanced science achievement between Black or Hispanic and White students. For example, the magnitude of Black-White disparity in the likelihood of advanced science achievement in first grade became smaller, from an odds ratio of .19 to .52, after additional predictors were added in Model 2. The disparity between Hispanic and White students was fully explained (i.e., odds ratio reduction from .26 [$p < .001$] to .90 [ns]). Science achievement in kindergarten was an especially strong explanatory factor of racial disparities in advanced science achievement in first grade. This factor's odds ratio was 3.58 ($p < .001$). The initially observed disparities between AINAPI and White students in first and third grade were fully explained.

Additional statistically significant predictors included the antecedent factors of family SES and gender, the opportunity factors of emergent literacy activities in the home, the average mathematics achievement of the school, and the propensity factors of the student's reading and mathematics achievement. Model 2's explanatory factors also substantially explained disparities in advanced science achievement between Black and White students in second, third, fourth, and fifth grade. These Black-White odds ratios were consistently reduced in size from an average percentage difference in relative odds of 80% to 49% (e.g., first grade's reduction from .19 to .52). The disparities between Hispanic and White students were substantially explained in fourth grade and fully explained in first, second, third, and fifth grade. These Hispanic-White odds ratios were also consistently reduced in size from an average percentage difference in relative

odds of 71% to 18%. Especially consistent predictors included the antecedent factors of family SES and gender, the opportunity factors of non-English use in the home (in second, third, and fifth grade), and the propensity factors of reading, mathematics, and science achievement. Kindergarten science achievement was an especially strong and consistent explanatory factor.

Mathematics Achievement

Table 4's Model 1 indicated that large racial and ethnic disparities in advanced mathematics achievement occurred during each of the elementary grades. For Black and Hispanic students, the unadjusted odds ratios for advanced mathematics achievement ranged from .16 to .20 and .24 to .34 ($p < .001$), respectively. AINAPI students were initially less likely to display advanced mathematics achievement in second (OR = .37. and third grade (OR = .24), but these disparities were not statistically significant following a correction for multiple comparisons. In contrast, Asian students were more likely to display advanced mathematics achievement. Asian students were about twice as likely to display advanced mathematics achievement as White students by the end of fifth grade (OR = 1.88, $p < .01$).

Model 2's antecedent, opportunity, and propensity factors significantly explained the disparities in advanced mathematics achievement between Black or Hispanic and White students. For example, the estimated odds ratios in first grade between Black and White students became substantially attenuated from .16 ($p < .001$) to .41 ($p < .01$) after accounting for Model 2's explanatory factors. The average percentage difference in relative odds of advanced mathematics achievement from first to fifth grade between Black and White students was reduced from 81% to 51%. The disparity between Hispanic and White students was also substantially explained (i.e., odds ratio reduction from .24 [$p < .001$] to .63 [$p < .01$]). The average percentage difference in relative odds of advanced mathematics achievement between Hispanic and White students was

reduced from 72% to 24%. The initially observed disparities between AINAPI and White students in second and third grade were fully explained.

Mathematics achievement in kindergarten was an especially important explanatory factor of racial or ethnic disparities in advanced mathematics achievement. For example, this factor's odds ratio for first and fifth grade were 6.36 and 3.06 ($p < .001$), respectively. Additional statistically significant predictors included the antecedent factors of family SES and gender, the opportunity factors of school average mathematics achievement, and the propensity factors of student reading and science achievement. Model 2's explanatory factors substantially explained disparities in advanced mathematics achievement between Black and White students in first, second, third, fourth, and fifth grade. The disparities between Hispanic and White students were fully explained in second, third and fourth grade and substantially explained in first and fifth grade. Repeatedly statistically significant predictors also included the opportunity factors of non-English use in the home and school economic composition as well as the propensity factor of working memory.

Discussion

Overview of Findings

We analyzed a population-based cohort of U.S. elementary schoolchildren followed from the fall of kindergarten to the spring of fifth grade to examine the early onset and over-time stability of racial and ethnic disparities in advanced science and mathematics achievement. We also examined to what extent antecedent, opportunity, and propensity factors explained these disparities. We hypothesized that Black, Hispanic, or AINAPI students would be less likely to display advanced science or mathematics achievement by kindergarten as well as across the elementary grades. We further hypothesized that antecedent, opportunity, and propensity factors

by the end of kindergarten would explain these disparities, particularly the antecedent factor of family SES and the propensity factor of student academic achievement (Byrnes, 2020).

Findings were largely consistent with our hypotheses. Large racial and ethnic disparities in advanced science or mathematics achievement were already evident by the end of kindergarten. Large disparities were also evident at the end of first, second, third, fourth, and fifth grade. At the end of fifth grade, about 13% of White students and 22% of Asian students displayed advanced mathematics achievement. The contrasting percentages were 2% and 3% for Black and Hispanic students, respectively. About 7% of AINAPI students displayed advanced mathematics achievement at the end of fifth grade. These racial and ethnic disparities in advanced science and mathematics achievement were themselves fully or substantially explained by the study's antecedent, opportunity, and propensity factors. Particularly strong explanatory factors were the family's SES and the student's science or mathematics achievement by the end of kindergarten. Both science and mathematics achievement strongly predicted whether kindergarten students displayed advanced science or mathematics achievement at the end of first, second, third, fourth, or fifth grade.

Strengths and Limitations

Our study's strengths include analyses of a population-based cohort followed from kindergarten entry to the end of fifth grade, individually administered and psychometrically strong measures of science, mathematics, and reading achievement, and data collection including a wide range of student, family, and school factors. Our estimates are based on analyses of data collected from a nationally representative sample of U.S. elementary schoolchildren. Although propensity factors strongly predict achievement growth including in STEM (Byrnes, 2020; Morgan et al., 2016), these factors have not previously been included in studies examining racial

and ethnic disparities in advanced STEM achievement (NAEP, 2020; Rambo-Hernandez et al., 2019) including as early as kindergarten. By doing so, our study clarifies that student propensity factors by kindergarten strongly predict the early onset of racial and ethnic disparities in advanced STEM achievement throughout elementary school. Inclusion of these propensity factors in our regression models also helped to provide better estimates of the predictive utility of the study's additional explanatory factors.

Our study also has limitations. The ECLS-K: 2011's data collection only began after students entered kindergarten. Data collection then ended as students exited fifth grade. We are unable to report on the onset, stability, or explanatory factors of racial and ethnic disparities in advanced science or mathematics achievement before kindergarten, during middle and high school, or into adulthood. We also are unable to report on the specific types of science, mathematics, or reading skills (e.g., scientific inquiry, knowledge of basic operations, oral vocabulary) that most strongly predict the observed disparities. This is because NCES only makes available general science, mathematics, or reading achievement scores. Consequently, we are unable to report on domain-specific academic skills (e.g., knowledge about basic operations, problem solving, scientific inquiry, oral vocabulary) most strongly predictive of racial and ethnic disparities in advanced science and mathematics achievement. The term STEM includes other types of academic knowledge than science or mathematics achievement (Granovski, 2018). However, only these two types of STEM were assessed in the ECLS-K: 2011. We used antecedent, opportunity, and propensity factors measured by the end of kindergarten to explain racial or ethnic disparities at the end of each of the subsequent elementary grades. Doing so allowed us to report on direct effects of factors simultaneously adjusted for initial levels of science and mathematics achievement, thereby better identifying potential targets of

experimentally evaluated intervention efforts (VanderWeele, 2020). We also internally replicated our findings by separately examining each grade level. However, our analyses did not examine how these antecedent, opportunity, and propensity factors dynamically inter-relate over time including through indirect effects (Lewis & Farkas, 2017).

We operationalized advanced science or mathematics achievement as being above the 90th percentile of the total achievement distribution. Although (a) our use of a 90th percentile cut off is consistent with prior research (Bell et al., 2019; Plucker et al., 2010; Rambo-Hernandez et al., 2019) and (b) the findings were robust to using a more liberal 75th percentile or a more conservative 95th percentile cut off, other findings might have emerged using other cut offs including those indicative of extremely high achievement (e.g., 1-3%) and giftedness (e.g., McClain & Pfeiffer, 2012; Pennsylvania Department of Education, 2014). Relatedly, we operationalized advanced achievement as scores relative to the entire score distribution. Other findings might have emerged using other types of reference group operationalizations (e.g., Rambo-Hernandez & McCoach, 2014; Rambo-Hernandez et al., 2019). Some of the study's reporting relied on very small sample sizes, particularly those examining consistently advanced science or mathematics achievement by some racial or ethnic groups. Smaller sample sizes result in greater standard errors in the estimated coefficients. We were unable to include measures of early STEM attitudes and aspirations and how these may have predicted racial and ethnic disparities in advanced STEM achievement. Other work finds that gender disparities in STEM attitudes and aspirations emerge by kindergarten in analyses controlling for ability and, over time, predict lower likelihoods to pursue STEM degrees (Ceci et al., 2014). We were unable to include the experiential knowledge of marginalized groups through qualitative or mixed methods

research (Gillborn et al., 2018). Such research is needed to better understand the early experiences of talented Black, Hispanic, and AINAPI students and their families.

Study's Contributions and Implications

Our findings have theoretical and empirical implications. Our results are largely consistent with the antecedent-opportunity-propensity theoretical framework (Byrnes, 2020) in which a relatively small set of student, family, and school factors explains racial and ethnic disparities in STEM achievement (Byrnes & Miller, 2007; Byrnes & Wasik, 2009; Wang et al., 2013). We fully or mostly explained disparities between Hispanic or AINAPI students and White students. This suggests that the study's antecedent, opportunity, and propensity factors largely account for the observed disparities and so might constitute potential targets of economic and educational policies. The family's SES and the student's propensities for acquiring academic skills by kindergarten were consistently strong predictors of advanced STEM achievement during elementary school.

Although disparities between Black and White students were substantially explained, the study's many antecedent, opportunity, and propensity factors do not fully explain the racial disparities. For example, the antecedent, opportunity, and propensity factors fully explained the kindergarten Hispanic-White odds ratio in advanced science achievement from .26 ($p < .001$) to .90 (*ns*). The Black-White odds ratio was also substantially reduced from .19 ($p < .001$) to .52 ($p < .01$). Yet, and although substantially reduced, this and the other observed Black-White disparities were not fully explained and remained both practically and statistically significant. This suggests that additional antecedent, opportunity, and propensity factors not measured in our study have yet to be identified that fully explain racial disparities in advanced STEM achievement during elementary school. Put another way, a relatively small set of student, family,

and school factors largely explain Hispanic-White or American Indian/Native American-White disparities in advanced STEM achievement during elementary school. Yet Black-White disparities in advanced STEM achievement during elementary school are still large after extensively accounting for such factors. This unexplained Black-White gap in advanced science and mathematics achievement is consistent with prior work (Freyer & Levitt, 2004) finding that Black-White but not Hispanic-White achievement gaps in reading and mathematics among observationally similar kindergarten students increase over time, possibly due to Black students being more likely to attend lower quality schools and the increasing English proficiency of some Hispanic students. Further theoretical and empirical work that fully explains the early emergence of racial disparities specifically in advanced STEM achievement is needed.

Our study also has practical implications. The early onset of racial and ethnic disparities in advanced STEM achievement has been unclear. This is because the available work has either investigated achievement gaps generally during the primary grades (Fryer & Levitt, 2004; Henry et al., 2020; Morgan et al., 2016; Navarro et al., 2012; Reardon & Galindo, 2009; Von Hippel et al., 2018) or has only been able to report on disparities specifically in advanced STEM achievement during the upper elementary grades (NAEP, 2020; Rambo-Hernandez et al., 2019). By establishing that disparities in advanced STEM achievement are occurring as early as kindergarten and then continue occurring across the elementary grades, our study provides new empirical knowledge about the populations of talented Black, Hispanic, and AINAPI students. These populations are currently understudied (Irizarry, 2015).

One practical implication of these findings is that racial and ethnic underrepresentation in STEM is unlikely to only be the result of racialized K-12 educational processes, although these may certainly contribute or exacerbate such under-representation. This is because large and

stable disparities in advanced science and mathematics achievement already occur by the end of kindergarten and so very early in the context of children's K-12 school careers. Antecedent, opportunity, and propensity factors measured by the end of kindergarten then fully or substantially explain racial and ethnic disparities in advanced science or mathematics achievement in first, second, third, fourth, and fifth grade. The advantages of White and Asian students relative to Black, Hispanic, or AINAPI students in experiencing advanced science or mathematics achievement already occur by the start of formal schooling. These advantages may then differentially position White and Asian students to benefit from educational processes throughout elementary, middle, and high school. This suggests that policymakers, practitioners, and researchers interested in racial and ethnic equity in STEM talent development should pay greater attention to the economic and educational factors prior to, by, or soon after school entry already resulting in consistently large racial and ethnic disparities in advanced science and mathematics achievement throughout elementary school.

Our findings suggest that programs and policies designed to increase racial and ethnic representation in STEM, whether as indicated by expressed interest in STEM careers during middle or high school, college major or degree completion, or workforce participation, may need to be implemented prior to or by school entry. Yet most efforts to address STEM underrepresentation currently emphasize adolescence or early adulthood (e.g., Alvarado & Muniz, 2018; Casto & Williams, 2020; Hinton et al., 2020; Jelks & Crain, 2019; McGee, 2020; Riegle-Crumb et al., 2019; Rozek et al., 2019). This is despite STEM interest already declining by middle school as students begin viewing scientists as stereotypically White (Finson, 2010; Hachey, 2020; Wong, 2015). Racial and ethnic disparities in STEM career interest are already evident by the start of high school (Saw et al., 2018). Our results suggest that policies and

programs focused on STEM course-taking and workforce participation are likely insufficient. Instead, efforts to address racial and ethnic disparities in STEM course taking and workforce participation should focus more broadly on the social, economic, and educational processes by early childhood already resulting in inequities in advanced STEM achievement by elementary school (Peters, 2021).

Consistent with other work (Alexander et al., 2012; McClure et al., 2017; Olszewski-Kabilius et al., 2016; Tai et al., 2006), our findings suggest STEM talent development efforts for Black, Hispanic, or AINAPI students should begin by the primary grades. Interests and feelings of efficacy towards STEM may be especially modifiable during this early time period (Hachey, 2020; Morgan et al., 2016; Penner & Paret, 2008; Pringle et al., 2012). Teachers and friends are more likely to support STEM interests during elementary school (Rice et al., 2013). Our findings provide additional empirical support for STEM talent-development efforts by the early elementary grades by establishing that Black, Hispanic, or AINAPI students are already less likely to display advanced science or mathematics achievement by kindergarten and in subsequent elementary grades. Thus, large “leaks” in the metaphorical STEM pipeline occur by early childhood in the U.S. (Morgan et al., 2016), suggesting that the current emphasis on adolescence and adulthood (e.g., Hinton et al., 2020) may be too late to successfully address racial and ethnic disparities in STEM course taking, degree completion, and workforce participation. Addressing the early onset of racial and ethnic disparities in advance science and mathematics achievement through economic and educational policies prior to or by school entry may be necessary for expanding racial and ethnic representation in gifted education (Peters, 2021) and the STEM workforce (NAESM, 2011; National Science Foundation, 2021) as well as ensuring the nation’s scientific innovation and resulting economic competitiveness (Bell et al.,

2019; NAESM, 2011). Our findings indicating that racial and ethnic gaps in advanced science and mathematics achievement already occur by kindergarten is also consistent with prior work examining racial and ethnic gaps in academic achievement more generally (Kuhfeld et al., 2020; Morgan et al., 2016; von Hippel et al., 2018), and so again suggesting the potential importance of early childhood economic and educational policies and practices (Currie & Almond, 2011; Ladson-Billings, 2006; Reardon et al., 2021).

Programs and policies explicitly designed to support the early talent development of Students of Color also may be necessary. Black and Hispanic families often lack access to private tutoring or other supports and so are more likely to rely on schools to develop their children's talents (Plucker & Peters, 2016). Without such programs and policies, talented Students of Color are likely to continue to be under-served in U.S. elementary schools (Grissom & Redding, 2016). Our findings are also consistent with work examining gender disparities in advanced STEM achievement, which finds that early experiences and ecological factors help to explain disparities in advanced study in STEM (Ceci et al., 2014; Halpern et al., 2007).

Our study helps identify potential targets of such programs and policies. Consistent with prior work (Byrnes, 2020), we show that the antecedent factor of family SES and the student propensity factors of early science and mathematics achievement consistently and strongly explain racial and ethnic disparities in advanced STEM achievement. Because family SES is consistently and strongly related to children's likelihood of experiencing advanced science or mathematics achievement during elementary school, recently proposed economic policies to substantially reduce child poverty (e.g., expanded SNAP benefits, direct income transfers, and additional child tax credits) that should disproportionately benefit Black, Hispanic, or AINAPI students (Parolin et al., 2020) might also potentially help address the early onset of racial and

ethnic disparities in advanced science and mathematics achievement. Additional programs that increase children's early exposure to science and mathematics including through universal pre-K (Amadon et al., in press), preschool interventions (Dumas et al., 2019), or that use validated school-based instructional methods (e.g., peer-assisted tutoring, small-group instruction, play-based games) may also be of benefit (de Chambrier et al., 2021; Dietrichson et al., 2021).

We also add to the prior theoretical work by including additional antecedent and opportunity factors. For example, Byrnes (2020) recently identified home language use and disability status as variables not previously included in studies evaluating the antecedent-opportunity-propensity framework. Our findings suggest that disability status does not predict racial and ethnic disparities in advanced science or mathematics achievement in analyses accounting for student propensity factors. However, we do observe that non-English-language use in the home consistently predicts a greater likelihood of displaying advanced science or mathematics achievement in analyses adjusted for potential confounds. A theoretical explanation for this finding is that, for advanced students, bilingualism facilitates learning of the complex rules and procedures integral to STEM learning (Hartanto et al., 2018; Stocco & Prat, 2014). Consistent with this theoretical explanation and our empirical findings, children who are English Language Learners have recently been reported to be more likely to be identified as gifted during elementary school (Ricciardi et al., 2020).

What might be done to address large racial and ethnic disparities in advanced science and mathematics achievement already occurring during elementary school? One possibility would be the adoption of economic and educational policies and programs that help support early STEM experiences by addressing poverty, adverse childhood experiences, and the lack of access to high-quality childcare and preschool (McClure et al., 2017; Peters, 2021). Family SES by

kindergarten strongly predicts young children's knowledge about their natural and social worlds as well as their science achievement as they age (Morgan et al., 2016). School-level poverty fully explains the association between school racial segregation and achievement gaps (Reardon et al., 2021). Another possibility is to universally screen for advanced science and mathematics achievement to identify talented Black, Hispanic, and AINAPI students as early as the primary grades (Matthews & Rhodes, 2020; Plucker & Peters, 2016). Such universal screening might instead use standardized measures of cognitive and non-cognitive skills instead of teacher nominations and referrals (Card & Giuliano, 2016; McBee et al., 2016; Wai & Lakin, 2020; Wai & Worrell, 2020). This is because elementary school teachers may be less likely to recognize advanced achieving Students of Color, resulting in a lower access to enrichment activities and supports that may further support their talent development (Grissom & Redding, 2016; Irizarry, 2015). Use of universal screening using standardized measures has been shown to result in a much greater likelihood of participation by racially and ethnically diverse elementary students in enrichment programs (Card & Giuliano, 2016), with resulting in greater achievement growth by these students (Card & Giuliano, 2015). Economic and educational policies and programs that successfully address the onset of racial and ethnic disparities in advanced science and mathematics achievement by the primary grades should help support talented Students of Color attending U.S. schools, broaden participation in STEM courses, degrees, and employment, and advance the nation's economic competitiveness and scientific innovation.

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