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RESEARCH ARTICLE

Contextualizing Math-Related Strengths and Math Achievement: Positive Math Orientations, Social Supports and the Moderating Effects of Prior Math Knowledge

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Abstract
Ongoing policy discussions emphasize the need for more STEM professionals to keep the United States internationally competitive in scientific fields and industry. From a K-16 perspective, it is important to note that students' trajectories into STEM professions are often shaped by their high school experiences—especially in mathematics. Accordingly, this study employs a strength-based framework to examine students' high school math achievement with an emphasis on the role of their math-related personal and social strengths. This research uses data from the NCES High School Longitudinal Study, a large-scale national study that emphasizes students' math outcomes. Moderated regression was utilized to examine associations between students' high school math-related strengths and their math achievement, as well as how these relationships may differ based upon students' prior math achievement. The findings suggest that a number of students' strengths in math were positively related to their math achievement; however, some of these relationships differed base upon prior math achievement levels. Accordingly, while math-related strengths can be equally beneficial for students in some instances, in other instances there is a need to better understand these relationships with some nuance. Implications for K-16 STEM education policy, practice and research are discussed.

Keywords K-16 STEM education · Mathematics · Strength-based research

Student outcomes in science, technology, engineering and mathematics (STEM) have been a prevalent topic of discussion over the past few decades as the United States tries to maintain its position as a leader in science and innovation (The White House n.d.; U.S. Department of Education n.d.). Because of the need for more STEM professionals

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in particular scientific areas, there has been increased attention to promising strategies to increase the number of STEM majors and graduates within American higher education (Burt et al. 2019; Burt et al. 2018). In fact, a number of colleges and universities have developed STEM initiatives to help bolster STEM degree production (Williams 2014a, b), and a national conversation has emerged to help better understand the efficacy of these interventions (DePass and Chubin 2014, 2016; Chubin and DePass 2015). While these initiatives can provide a valuable bridge between higher education and industry, it is important to note that pathways to STEM careers begin before students enter college. Students' STEM exposure and related experiences in K-12 help to shape their trajectories into STEM majors and later careers. Recent federal policy initiatives emphasize this focus and underscore it as an area of national concern. For example, the White House National Science and Technology Council recently announced an aggressive five-year strategic plan for STEM education to position the United States as a global leader in STEM literacy, innovation, and employment (White House Office of Science and Technology Policy, 2018). This multipronged plan focuses partially on colleges and universities as key components of the overall STEM ecosystem; however, it also notes that "Basic STEM concepts are best learned at an early age—in elementary and secondary school—because they are the essential prerequisites to career technical training, to advanced college-level and graduate study, and to increasing one's technical skills in the workplace" (White House Office of Science and Technology Policy, 2018, p. v.). Therefore, it is important that educational and policy efforts to increase the number of STEM professionals acknowledge the key role of students' STEM-related experiences during K-12 as well as higher education.

While some research indicates that students' academic experiences as early as middle school have important implications for their later success in STEM fields (Williams et al. 2016, 2019), high school also plays an important role—especially in relation to students' STEM postsecondary plans. Students' pathways into STEM often begin before entering college (Aschbacher et al. 2010; Bottia et al. 2015; Eris et al. 2010; Tyson et al. 2007; Wang 2013), and many students start to formulate decisions about choice of majors during high school. Also, students' high school academic exposure has a great influence on their access to STEM fields in college. A number of studies highlight the importance of high school in students' postsecondary STEM trajectories (French et al. 2005; Gottfried and Plasman 2018; Means et al. 2018; Zhang et al. 2004). Accordingly, it is important to understand students' academic experiences at this critical juncture in order to address the larger policy interest of increasing the number of STEM majors and STEM graduates. This study seeks to investigate these experiences with a particular focus on mathematics, given the federal policy emphasis on increasing math success to decrease barriers to STEM careers (White House Office of Science and Technology Policy, 2018), and existing research which notes how math can influence students' trajectories into STEM majors and careers (Tyson et al. 2007; Wang 2013).

This research examines key factors that influence students' high school math achievement with an emphasis on their math-related psychological attributes and social supports. It employs a strength-based framework to position these factors as personal and social strengths and builds upon existing literature which notes the positive impact of such social and psychological factors on students' math success (Jones et al. 2010; Ting and Man 2001). Moreover, this study seeks to better understand how these social and psychological factors relate to math success with some nuance. In doing so, these analyses explore the degree to which the relationship between these math-related psychological orientations, social supports and math achievement may differ based upon an important background characteristic—students' prior math understanding. The following specific research questions guide this study:

1) How do students' math-related personal and social strengths relate to their math achievement in high school?
2) Does the relationship between these math-related strengths and math achievement differ based upon students' prior math achievement?

Theoretical Orientation

A number of theories have been used previously to better understand various factors which affect math achievement. With regard to personal attributes, scholars have examined how psychological orientations such as a growth mindset (Blackwell et al. 2007; Dweck 2007), and expectancy-value theory (Meece et al. 1990; Wang and Degol 2013) can impact students' math achievement along the K-12 spectrum. Collectively, these studies suggest that students' psychological attributes can have a drastic impact on mathematics success. Other research has promoted the use of an ecological framing to assess how individual and environmental factors influence math achievement levels (Fantuzzo et al. 2012; Kotok 2017; Stinson, 2006; Strayhorn 2010). Some of this research focuses on nested systems, their related roles, norms and rules and how each of these can influence student development (Strayhorn 2010). Such an approach not only considers the role of students' psychological orientations in math achievement, but also family characteristics and school environment, along with other historical, social and cultural forces. While research that uses an ecological framing goes beyond other studies that focus solely on psychological attributes and jointly examines social and psychological (i.e. psycho-social) factors that influence math achievement, additional research is needed which explores how relationships between psycho-social factors and math achievement may differ based upon important student characteristics. The Bowman Role Strain and Adaptation Model (BRSAM) (Bowman 2006) provides useful conceptual guidance that can be used to better understand how students' math-related psycho-social attributes relate to their math achievement with some nuance that acknowledges other key student characteristics.

The BRSAM is informed by a lineage of role strain theory used in a number of fields such as sociology (Goode 1960), psychology (Bowman 1985, 2006), health (Griffith et al. 2011), and more recently, education (Author, Year a). In general, role strain theory posits that individuals can encounter various life challenges or difficulties (i.e., strains) that have the potential to deter successful outcomes in a given life role (Goode 1960). Building upon role strain theory, the BRSAM focuses on students and acknowledges that the strains which students encounter may hinder successful outcomes. However, as a strength-based framework, the BRSAM also suggests that the multilevel strengths (MLS) students bring to their educational environments can help to promote success despite their strains. Some of these strengths manifest at the personal level as individual attributes that help to foster student success (e.g., high levels of self-efficacy, resilience and identity). Other strengths exist at the social level, such as support from family, friends, school peers and other significant individuals—each of which can also help students to succeed despite strains. To fully understand the nature and influence of these strengths on student success, the model argues that they must be examined within the context of other key factors regarding students' background and life experiences. Framing the relationship between strengths and student success in this manner provides a cohesive picture of how various social and psychological factors combine to influence student outcomes.

Building upon the BRSAM, this study examines how the personal and social strengths that students bring to educational environments influence their high school math achievement. Furthermore, these analyses explore how this relationship may differ based on an important background characteristic—students' prior math achievement. Because of the emphasis on math, this research examines students' personal and social strengths that are directly related to this subject.

Literature Review

Research illustrates how various factors can operate as strengths that facilitate successful math outcomes. For example, extant research has focused on psychological and social factors such as personal attributes (e.g., math identity, math self-efficacy, math interest, math utility) or social support systems (e.g., family, peer, school) that can positively influence students' math outcomes (Ahmed et al. 2010; Erturan and Jansen 2015; Syed et al. 2011). The following sections discuss existing literature regarding math-related psychological orientations and family academic support. Guidance from the BRSAM is employed in this literature review to articulate how these factors can serve as multilevel strengths to promote math achievement.

Positive Psychological Orientations as Personal Strengths in Mathematics

Many studies have noted the importance of students' identification with a subject area relative to their success in that subject (Aschbacher et al. 2010; Brotman and Moore 2008; Williams and George-Jackson 2014). As this relates to mathematics, the literature generally suggests that students who identify with mathematics (i.e., those with high levels of math identity) have more successful math outcomes. Math identity represents a student's perceived association between math and self (Nosek et al. 2002). A greater alignment between math and the student's sense of self represents a higher level of math identity. Furthermore, a higher level of math identity promotes greater math achievement (Syed et al. 2011; McGee and Pearman II 2014).

In addition to math identity, the positive association between math self-efficacy and math achievement is also commonly noted in the literature (Liu and Koirala 2009; Pantziara 2016; Skaalvik et al. 2015). As a psychological construct, self-efficacy is generally defined as the "belief in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura 1997, p. 3). Building upon this definition, math self-efficacy is a student's context-specific evaluation of his or her competence to execute and perform certain math-related tasks (Pajares and Miller 1994; Usher and Pajares 2008). Erturan and Jansen (2015) examined how students' psychological orientations towards mathematics relate to their math achievement with an emphasis on math self-efficacy and math self-concept. The results suggest that students with more positive psychological orientations also have greater success in the subject. Specifically, when students have an increased level of math self-efficacy (i.e., belief, competence, confidence in their ability to do and succeed in math) and math self-concept (i.e., belief in themselves), they are more likely to have higher levels of math achievement (Murayama et al. 2013). Also, students who possess higher levels of math self-efficacy are more likely to demonstrate greater interest, effort, persistence, and help-seeking behavior, which can also lead to increases in math achievement (Skaalvik et al. 2015).

Support as a Social Strength in Mathematics

In addition to the personal strengths that students bring to academic environments, their social supports can serve as sources of strength that are influential to their achievement. One source of social support often cited in the literature is family. Existing studies consistently emphasize the importance of parental support and involvement (i.e., family support) in students' academic achievement (Howard and Reynolds 2008; Jeynes 2007; Mandara et al. 2009). That is, students whose parents are more active and engaged in their education generally have better academic performance than students whose parents are less involved (Jeynes 2007; Mandara et al. 2009). Thus, students that have greater academic family support demonstrate higher levels of math achievement. As a complement to family support, there is also evidence that social support from peers and teachers helps to promote student achievement in mathematics (Ahmed et al. 2010; Garcia-Melgar and Meyers 2020). Research suggests that support from each of these groups not only improves math achievement but is also positively associated with other important math outcomes such as students' math enjoyment and perceived competence (Ahmed et al. 2010). Accordingly, support from family, friends and teachers can help foster students' math success in multiple domains.

While each body of work previously noted provides insights about key social and psychological factors associated with positive math outcomes, the question remains as to whether or not these factors operate differently for different types of students. Moreover, given the emphasis on students' math-related psychological orientations and social supports in STEM education practice, it is especially important to determine if the relationships between these elements and math achievement differ for students with varying levels of prior math achievement. Building upon existing research, this study seeks to fill this gap in the literature by using a strength-based theoretical framework to examine the influence of students' math-related MLS on math achievement in high school and how those relationships may fluctuate based on students' prior math understanding.

Methods

Sample and Data

This research uses data from the High School Longitudinal Study of 2009 (HSLS:09). HSLS:09 is one of several large-scale school-based longitudinal studies conducted by the National Center for Education Statistics (NCES). The overall dataset includes information about various topics with an emphasis on students' experiences in STEM (Ingels et al. 2013). HSLS:09 data was collected using a 2-stage stratified random sampling procedure to identify students at public and private schools within the United States. The HSLS:09 sample is nationally representative of students in the US who started 9th grade in 2009. In the first stage of sampling, approximately 1900 eligible schools were identified. School recruitment efforts were facilitated by endorsements from various nationally recognized organizations that work closely with school administrators, counselors, teachers, students and parents. These organizations include the American Association of School Administrators, the American Federation of Teachers, and the National Education Association among others. As part of recruitment, the chief state school officers, as well as the superintendent of each public school district and diocese containing sampled schools, were contacted for approval from the appropriate representatives. Non-Catholic private schools were contacted directly. In addition, administrators at each of the sampled schools were contacted for study approval and to coordinate logistical details. About half of eligible schools participated (Ingels et al. 2013).

In the second stage of the sampling procedure, students were randomly sampled from enrollment lists. Over 80 % of students who were identified for the study ultimately participated. Students were initially surveyed in 9th grade during the Fall of 2009. Follow-up surveys were administered in 2012—when most of the students in the cohort were in the second semester of the 11th grade—and in 2016—three years after most would have graduated. Student participants were given a "goody bag" as a token of appreciation. Each assessment and survey was generally administered online during in-school sessions (Ingels et al. 2013).

Because this study focuses on students' math-related strengths and math content knowledge in high school, data from the base year and first follow-up are used. In these analyses, the key predictors and control variables are generally from the base-year survey, and the outcome variable is measured during the first follow-up survey. The sample for the study was limited to students who had 1) data from the base-year and first follow-up, and 2) scores on the 11th grade mathematics assessment. Because this study focuses on single-level analyses, a design-based approach was used to address homogenous clusters within the data (Hahs-Vaughn 2005; Thomas and Heck 2001). Specifically, a design effects adjusted weight was used in SPSS to account for complex sampling design (Hahs-Vaughn 2005). The estimated unweighted sample for this study is 14,227. The analytic sample size is $N = 3150$ after using a design effect adjusted weight. Results are generalizable to the 2009 cohort of 9th grade students who were also in the 11th grade in 2012.

Measures

This study employs various measures to tap students' math-related MLS at two levels—the individual level and the social level. Individual levels strengths are measured based upon key psycho-social attributes related to mathematics. Moreover, social strengths are operationalized using measures for students' math-related social supports. In addition to math-related MLS, variables of key background characteristics are included in these analyses.

As previously noted, this study examines theoretical relationships suggested by the Bowman Role Strain and Adaptation Model (BRSAM) and how these may manifest differently based upon a key background characteristic—prior math achievement. Accordingly, a discussion of the relative effects of individual measures is beyond the scope of this paper. However, the outcome and continuous measures have been standardized to allow the reader some insight about effect size. The following discussion provides information about these measures. Additionally, Table 1 includes variable description and coding information.

Positive Psychological Math Orientations Students' personal strengths are measured using various constructs which describe positive psychological orientations towards mathematics. These include math self-efficacy, math identity, math interest and math utility. Each construct is measured using National Center for Education Statistics (NCES) composites. Also, each has a fair to high level of internal consistency, with a Cronbach's Alpha minimum of 0.65 (Ingels et al. 2013). For each composite, an increase in students' scores on a given measure indicates a more positive psychological orientation towards mathematics.

Math self-efficacy is tapped with survey items concerning students' beliefs in their ability to do math. Students were asked to use a four-point Likert scale with ratings ranging from "strongly agree" to "strongly disagree" to respond to statements such as the following: "you are confident that you can do an excellent job on tests in your current math course"; "you are certain that you can understand the most difficult material presented in the textbook used in this course"; and "you are certain that you can master the skills being taught in this course." In addition to math self-efficacy, math identity is also used as a measure of students' strengths at the personal level. Math identity indicates the degree to which students relate to or have a personal association with math as a subject. Survey items used to create this construct include students' responses to statements such as: "you see yourself as a math person"; and "others see you as a math person". Again, responses were provided on a four-point Likert scale ranging from "strongly agree" to "strongly disagree."

In addition to self-efficacy and identity, measures for students' math interest and math utility are also included. The math interest construct provides insight about students' perceptions of the subject (i.e., math is boring, a waste of time, etc.) and includes students' reactions to statements such as: "you are enjoying your current math course very much"; "you think your current math course is a waste of your time"; and "you think your current math course is boring." Moreover, the math utility construct provides insight about the degree to which

Table 1 Variable descriptions and coding information

Independent Variable	Variable Description	Variable Type	Variable Coding	Source
Background Characteristics				
Female	Student's gender	Dichotomous	1 = Female; 0 = Male	BY Survey
Socioeconomic Status	Family socio-economic background	Continuous		BY Survey
Underrepresented Student of Color	Student is a member of a racial/ethnic group that is underrepresented in STEM	Dichotomous	1 = Hispanic, Black/African American, Native American/Alaska Native, or Native Hawaiian/ Pacific Islander; 0 = Not Hispanic, Black/African American, Native American/Alaska Native, or Native Hawaiian/Pacific Islander	By Survey
Multi Race	Student identfies as multi-racial	Dichotomous	1 = Multi-racial; 0 = Not Multi-Racial	BY Survey
Prior Math Achievement	9th grade math assessment score	Continuous		BY Survey
Math-Related Multilevel Strengths				
Math Identity	Degree to which student relates to or has a personal association with math as a subject	Continuous		BY Survey
Math Self-Efficacy	Student's belief in their ability to do math	Continuous		BY Survey
Math Interest	Student's interest in math	Continuous		BY Survey
Math Utility	Degree to which student perceives math course would be helpful in life, college or their future careers	Continuous		BY Survey
General Math-Related Social Support	Degree to which student consulted with parents, peers, favorite teacher and school counselor about math course-taking	Continuous		BY Survey
Math-Related Social Group	Student participation in various math-related social groups since the beginning of high school	Dichotomous	1 = Participated in math club, math competition, math summer programs, math study groups, or math tutoring; 0 = Did not participate	1st FU Survey
Outcome Variable				
11th Grade Math Achievement	11th grade math assessment score	Continuous		1st FU Survey

BY = Base year survey; FU = Follow-up survey students perceive that their math course would be helpful in life, college or their future careers. The corresponding survey items for this construct include: "your current math course is useful for everyday life"; "your current math course will be useful for college"; and "your current math course will be useful for a future career." Responses for the math interest and math utility items were measured on a four-point Likert scale ranging from "strongly agree" to "strongly disagree."

Math-Related Social Supports As a complement to students' personal strengths, students' math-related social supports are also assessed. This study focuses on the social support that students receive in two domains—the general math support received during their math course selection process and the targeted supports received through participation in math-related social clubs.

General support in math is measured by students' responses to items concerning their math-related interactions with their parents, peers, favorite teacher and school counselor. Students were asked whether they consulted with each of these individuals about which math courses to take. These items were averaged to create a general math support composite score, and the construct is measured with a fair degree of internal consistency ($\alpha = 0.59$).

In addition to support from peers and influential adults, this research also examined students' participation in math-related social clubs or similar activities to measure their exposure to targeted math-related social support. To operationalize this construct, items were employed that inquired about students' retroactive participation in the following activities since the beginning of Fall 2009: math club, math competition, math summer programs, math study groups, and math tutoring. This information was used to create a dichotomous measure where 1 indicated participation in at least one of these activities, and 0 indicated non-participation for each of these activities.

Background Characteristics To better understand how students' math-related MLS in 9th grade related to their 11th grade math achievement, it is important to account for key demographic characteristics that may also relate to the outcome. Accordingly, this study included measures of students' gender, family socio-economic status (SES), and race/ethnicity. In terms of gender, the original variable in the data was recoded so that males were given a value of 0 and females a value of 1. To account for individual math assessment differences that may manifest due to students' social and economic backgrounds, an NCES-created SES composite measure was included. This measure captures students' socio-economic status based on their parents' or guardians' education, parents' or guardians' occupation, and their family income (Ingels et al. 2013). With regard to race/ethnicity, this study compared the math scores of underrepresented students of color in STEM (i.e., Hispanic, Black/African American, Native American/Alaska Native, or Native Hawaiian/Pacific Islander) and multiracial students to those of students who are White or Asian. Accordingly, White and Asian students serve as the reference group. In these analyses, it was also important to account for students' prior understanding of math content; hence, a measure of students' math knowledge during 9th grade was included.

Analytic Approach

As previously noted, this analysis used a design-based approach to address homogeneous clusters within the data. Specifically, design effect adjusted weights were utilized to account for a complex sampling design. Such an approach is suitable given the focus on single-level analyses (Hahs-Vaughn 2005; Thomas and Heck 2001). The analyses in this study proceeded from descriptive statistics to multivariate models. To begin exploring relationships among the various measures in this study, a series of descriptive analyses were conducted. First, overall descriptive statistics were examined. Next, differences in key measures based on 9th grade math scores were also investigated. In doing so, the 9th grade math assessment score was disaggregated into quartiles, and chi-square tests or analyses of variance were employed to examine any differences in math-related strengths and demographics based on students' 9th grade math score.

In addition to descriptive analyses, bivariate relationships were examined between each of the measures previously discussed. In doing so, Pearson's correlation coefficients were calculated as an initial exploration of how each measure relates to the outcome. Thereafter, multiple regression analyses were conducted to better assess how student strengths relate to the outcome while accounting for other important factors. Because the outcome for this study—11th grade math achievement—is continuous, ordinary least squares (OLS) was an appropriate analytic technique (Chatterjee and Hadi 2015). Seven OLS regression models are considered. The first model is outline in eq. 1 and examines the main effects of students' math-related MLS on their 11th grade math achievement after accounting for prior achievement and key demographic characteristics.

$$\begin{gathered}\mathbf{11^{th}\ Grade\ Math\ Knowledge} = {}_0 + {}_1 \text{ Prior Math Achievement} + {}_2 \text{ Math ID} \\ +_3 \text{ Math SE} + {}_4 \text{ Math Int} + {}_5 \text{ Math Util} + {}_6 \text{ Gen Math Support} \\ +_7 \text{ Math}-\text{Related Social Groups} + {}_8 \text{ Female} + {}_9 \text{ Underrep SOC} + {}_{10} \text{ Multi}-\text{Racial} \\ +_{11} \text{ SES} + \end{gathered} \tag{1}$$

Models 3 through 7 are represented by eq. 2. This model adds an interaction term to eq. 1 to examine potential moderating effects of students' prior math knowledge on the relationship between a particular MLS and 11th grade math score. An interaction term between each MLS and prior math achievement was created and separate models were estimated, each considering a single interaction term.

$$\begin{gathered}\mathbf{11^{th}\ Grade\ Math\ Knowledge} = {}_0 + {}_1 \text{ Prior Math Achievement} + {}_2 \text{ Math ID} \\ +_3 \text{ Math SE} + {}_4 \text{ Math Int} + {}_5 \text{ Math Util} + {}_6 \text{ Gen Math Support} \\ +_7 \text{ Math}-\text{Related Social Groups} + {}_8 \text{ Female} + {}_9 \text{ Underrep SOC} + {}_{10} \text{ Multi}-\text{Racial} \\ +_{11} \text{ SES} + {}_{12} \text{ MLS Measure x Prior Math Achievement} + \end{gathered} \tag{2}$$

where MLS Measure = Math ID, Math SE, Math Int, Math Util, Gen Math Support, or Math-Related Social Groups.

Plots were created for significant interaction terms to facilitate the interpretation of moderating effects.

A small number of measures within the models were missing data. Results from Little's Missing Completely at Random (MCAR) Test suggest that data was missing completely at random. Accordingly, listwise deletion was employed throughout these analyses. Because this study uses large-scale national data, this approach is feasible without potential power issues.

Findings

Descriptive Statistics and Correlation Analyses

Table 2 provides information about the math-related MLS, and background characteristics for the overall sample. Thirty-four percent of students in these analyses were underrepresented students of color, and 8 % were multiracial. A little over half was female. Twenty-five percent of the students in the study indicated participation in a math-related social group.

Table 3 indicates correlations between students' background characteristics, MLS and 11th grade math achievement. In terms of background characteristics, students' SES was moderately and positively correlated with the outcome ($r = .41,\ p < .001$). Conversely, being an underrepresented student of color was weakly and negatively related to math score ($r = -.23,\ p < .001$). However, multi-racial identity was not significantly related to math achievement. Also, gender was not related to the outcome—a finding aligned with other research which suggests potential

Table 2 Descriptive statistics

Measure		Mean	SD	Min	Max
Outcome	11th Grade Math Achievement	64.47	18.69	26.76	115.10
Background	Female	0.51	0.50	0.00	1.00
	Socio-economic Status	0.01	0.74	−1.93	2.88
	Underrepresented Student of Color	0.34	0.47	0.00	1.00
	Multi-Racial	0.08	0.27	0.00	1.00
	Prior Math Achievement	55.89	15.47	103.79	25.10
Math-Related Multilevel Strengths	Math Identity	0.04	1.00	−1.73	1.76
	Math Self-Efficacy	0.02	0.98	−2.92	1.62
	Math Interest	0.02	0.99	−2.46	2.08
	Math Utility	0.01	1.00	−3.51	1.31
	General Math-Related Social Support	0.33	0.28	0.00	1.00
	Math-Related Social Group	0.25	0.43	0.00	1.00

~$p < .10$; *p < .05; **$p < .01$; ***$p < .001$

Table 3 Correlations between background characteristics, math-related multilevel strengths and math achievement

Measure	2										
1. 11th Grade Math Achievement	−0.02	0.41 ***	−0.23 ***	−0.01	0.73 ***	0.36 ***	0.28 ***	0.18 ***	−0.01	0.26 ***	0.11 ***
2. Female	–	0.00	0.02	0.02	−0.01	−0.05 **	−0.09 ***	0.01	−0.03 ~	0.07 ***	0.09 ***
3. Socio-economic Status		–	−0.36 ***	0.01	0.42 ***	0.12 ***	0.12 ***	0.03	−0.07 ***	0.23 ***	0.10 ***
4. Underrepresented Student of Color			–	−0.21 ***	−0.24 ***	−0.04 *	−0.02	0.02	0.10 ***	−0.15 ***	0.04 *
5. Multi-Racial				–	−0.01	0.00	−0.01	−0.02	−0.01	0.01	0.00
6. Prior Math Achievement					–	0.38 ***	0.29 ***	0.20 ***	0.00	0.27 ***	0.08 ***
7. Math Identity						–	0.57 ***	0.54 ***	0.29 ***	0.22 ***	0.07 ***
8. Math Self-Efficacy							–	0.54 ***	0.36 ***	0.16 ***	0.05 **
9. Math Interest								–	0.43 ***	0.17 ***	0.06 **
10. Math Utility									–	0.06 ***	0.03
11. General Math-Related Social Support										–	0.13 ***
12. Math-Related Social Group											–

~p < .10; *p < .05; **p < .01; ***p < .001

improvements of long-standing gender gaps in math success (Cheema and Galluzzo 2013; Hyde et al. 2008).

Regarding students' prior math assessment and math-related strengths, both are related to 11th grade math achievement. Prior math scores were positively and strongly correlated with the outcome (*$r = .74$, $p < .001$*), and most indicators of students' MLS were also positively associated with 11th grade math score. In terms of psychological orientations, students' math identity and math self-efficacy had moderate positive relationships with the outcome (*$r = .36$, $p < .001$* and *$r = .28$, $p < .001$,* respectively). In addition, math interest had a small positive relationship with math score (*$r = .18$, $p < .001$*). Regarding math-related social supports, students' general support was moderately and positively related to math score (*$r = .27$, $p < .001$*), and their social group participation was weakly and positively related to the outcome (*$r = .11$, $p < .001$*).

Table 4 provides deeper insights about the study sample by examining students' 11th grade math achievement and MLS disaggregated by their prior math assessment score. To facilitate these analyses, the measure for 9th grade math score was divided into quartiles. Students with low 9th grade math scores are those in the lowest quartile, and students with high scores are those in the highest quartile.

In terms of students' math-related MLS, students in lower 9th grade math achievement quartiles generally had lower levels of strengths relative to their peers in higher quartiles. For example, an analysis of variance indicated statistically significant differences in math identity by prior math achievement level $F(3, 3145) = 151$, $p < .001$). Furthermore, post hoc analyses using the Bonferroni criterion for significance suggested that the average level of math identity for each group is significantly different from those of the other groups. Accordingly, students with higher levels of math achievement in 9th grade also had higher levels of math identity. At the social level, a chi-square test of independence indicated overall significant differences in students' math-related social group participation by their level of prior math knowledge, X^2 $(3, N = 3148) = 23.94$, $p < .001$. However, post hoc analyses indicate that these differences primarily manifest when comparing the students with the highest level of prior math knowledge (i.e., the 4th quartile) to other groups. While 22% to 24% of students in the low, low to mid and mid to high prior math achievement quartiles participated in a math-related social group, 32% of the students in the highest prior math achievement quartile participated in these activities.

Math-Related Multilevel Strengths and High School Math Achievement

Model 1 in Table 5 provides insight about the main effects of key background characteristics and math-related MLS on math achievement in the 11th grade. Results from the linear regression suggest a significant association between students' background characteristics, math-related multilevel strengths and 11th grade math score ($F(11, 3138 = 371.99$, $p < .001$, $R^2 = .57$). On average, students with greater 9th grade math achievement also had greater 11th grade math achievement ($B = .63$, $p < .001$). In addition, Model 1 also indicates that a number of students' math-related MLS were positively associated with the outcome. These positive relationships manifested even after accounting for students' prior math achievement and controlling for important background characteristics.

Table 4 Descriptive statistics for students by prior math achievement

Prior Math Achievement	Low ($N = 787$)		Low to Mid ($N = 788$)		Mid to High (N = 788)		High (N = 787)		Post Hoc Comparison: Low vs Low to Mid	Low vs Mid to High	Low vs High	Low to Mid vs Mid to High	Low to Mid vs High	Mid to High vs High
	Mean	SD	Mean	SD	Mean	SD	Mean	SD						
Outcome														
11th Grade Math Achievement	50.13	13.19	60.05	13.25	70.71	13.51	85.00	14.00	***	***	***	***	***	***
Multilevel Strengths														
Math Identity	−0.39	0.96	−0.14	0.95	0.15	0.93	0.55	0.87	***	***	***	***	***	***
Math Self-Efficacy	−0.31	1.02	−0.13	0.91	0.13	0.94	0.39	0.91	**	***	***	***	***	***
Math Interest	−0.26	1.00	−0.04	0.98	0.09	0.98	0.27	0.95	***	***	***	*	***	**
Math Utility	0.02	1.07	0.02	0.99	0.00	0.96	−0.01	0.97						
General Math-Related Social Support	0.24	0.25	0.29	0.26	0.35	0.28	0.44	0.29	**	***	***	***	***	***
Math-Related Social Group	0.22	0.41	0.24	0.43	0.23	0.42	0.32	0.47			***		**	***

~p < .10; *p < .05; **p < .01; ***p < .001

At the individual level, there is mixed evidence concerning how personal strengths during 9th grade relate to math achievement in 11th grade. The findings suggest that math identity helps to foster students' understanding of math content. Specifically, students with a higher level of math identity in 9th grade also had higher 11th grade math scores ($B = .08$, $p < .001$). In addition, math self-efficacy may promote increases in the outcome. As shown in Model 1, students with higher levels of math self-efficacy in 9th grade earned higher scores on their 11th grade math assessment ($B = .05$, $p < .01$).

Although the positive association between math identity and self-efficacy indicate that these psychological factors may help to increase math achievement, a different relationship exists for students' opinions about the utility of mathematics and their interest in the subject. While 9th grade math interest was not significantly related to 11th grade math score ($B = -.01$, p = n.s.), the results in Model 1 suggest that math utility may be negatively associated with the outcome ($B = -.03$, $p < .05$). Hence, students' interest in math was not related to their math score, and those with more positive conceptions about the subject's usefulness may also have lower test scores.

In terms of social strengths, Model 1 indicates that social support in mathematics during 9th grade is positively associated with 11th grade content knowledge. Higher levels of general support in the course selection process was positively associated with students' math scores ($B = .04$, $p < .01$). In addition, students with math-related social interactions also had math scores that were higher than those without such interactions ($B = .09$, $p < .01$).

Moderated Math-Related Strengths: A Closer Examination of Prior Math Achievement

In addition to the main effects presented in Model 1, this study also investigates whether the relationship between math-related MLS and 11th grade math achievement differs based on students' prior math achievement. Table 5 Models 2 through 7 include interaction terms between prior math knowledge and measures for math-related MLS to examine variations in these relationships. While no significant moderating effects manifest for some models, evidence suggests a significant interaction between prior math achievement and the following MLS: math identity, math self-efficacy and math interest. Figures 1, 2 and 3 depicts these interactions to illustrate how the association between these strengths and the outcome varies for students with different levels of prior math achievement. In doing so, the relationship between the indicated strength and 11th grade math achievement is examined for students within each 9th grade math assessment quartile (low, low to mid, mid to high and high). As suggested by the main effects model, Fig. 1 illustrates a positive relationship between math identity and math achievement regardless of students' prior math score; however, the magnitude of this relationship increases as students' prior math achievement increases. Only a slight positive relationship between math identity and 11th grade math achievement exists for students within the lowest 9th grade math quartile. On the other hand, the strongest positive relationship between these two factors manifests for students with the highest level of prior math achievement (i.e., those in the highest quartile). Hence, students with higher levels of prior math achievement appear to benefit the most from high levels of math identity. Similar moderated relationships exist between math self-efficacy and math achievement (Fig. 2). Although the main effects in Model 1 suggest no significant overall association between math interest and 11th grade math

Table 5 Moderated regression analysis assessing the influence of math-related strengths on 11th grade math achievement

Independent Variable	Model 1: Main Effects		Model 2: Identity Interaction		Model 3: Self-Efficacy Interaction		Model 4: Interest Interaction		Model 5: Utility Interaction		Model 6: Social Support Interaction		Model 7: Social Group Interaction	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Background Characteristics														
Female	−0.03	0.02	−0.02	0.02	−0.02	0.02	−0.03	0.02	−0.03	0.02	−0.03	0.02	−0.03	0.02
Socioeconomic Status (a)	0.11 ***	0.01	0.11 ***	0.01	0.11 ***	0.01	0.11 ***	0.01	0.11 ***	0.01	0.11 ***	0.01	0.11 ***	0.01
Underrepresented Student of Color	−0.06 *	0.03	−0.06 *	0.03	−0.06 *	0.03	−0.06 *	0.03	−0.06 *	0.03	−0.06 *	0.03	−0.06 *	0.03
Multi Race	−0.02	0.05	−0.01	0.05	−0.02	0.05	−0.02	0.05	−0.02	0.05	−0.02	0.05	−0.02	0.05
Prior Math Achievement	0.63 ***	0.01	0.63 ***	0.01	0.62 ***	0.01	0.62 ***	0.01	0.63 ***	0.01	0.62 ***	0.02	0.62 ***	0.02
Math-Related Multilevel Strengths														
Math Identity (a)	0.08 ***	0.02	0.08 ***	0.02	0.08 ***	0.02	0.08 ***	0.02	0.08 ***	0.02	0.08 ***	0.02	0.08***	0.02
Math Self-Efficacy (a)	0.05 **	0.02	0.05 **	0.02	0.04 **	0.02	0.05 **	0.02	0.05 **	0.02	0.05 **	0.02	0.05 **	0.02
Math Interest (a)	−0.01	0.02	−0.01	0.02	−0.01	0.02	−0.02	0.02	−0.02	0.02	−0.01	0.02	−0.01	0.02
Math Utility (a)	−0.03 *	0.01	−0.03 *	0.01	−0.03 *	0.01	−0.04 *	0.01	−0.03 *	0.01	−0.03 *	0.01	−0.03 *	0.01
General Math-Related Social Support (a)	0.04 **	0.01	0.04 **	0.01	0.04 **	0.01	0.04 **	0.01	0.04 **	0.01	0.04 **	0.01	0.04 **	0.01
Math-Related Social Group	0.09 **	0.03	0.08 **	0.03	0.08 **	0.03	0.08 **	0.03	0.09 **	0.03	0.09 **	0.03	0.08 **	0.03
Math Identity x Prior Math Achievement			0.04 **	0.01										
Math Self-Efficacy x Prior Math Achievement					0.04 ***	0.01								
Math Interest x Prior Math Achievement							0.03 **	0.01						
Math Utility x Prior Math Achievement									0.02	0.01				
General Math-Related Social Support x Prior Math Achievement											0.00	0.04		
Math-Related Social Group x Prior Math Achievement													0.02	0.03

Table 5 (continued)

Independent Variable	Model 1: Main Effects		Model 2: Identity Interaction		Model 3: Self-Efficacy Interaction		Model 4: Interest Interaction		Model 5: Utility Interaction		Model 6: Social Support Interaction		Model 7: Social Group Interaction	
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE
Constant	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03	0.02
Fit Statistics														
R-Square (R^2)	0.566 ***		0.567 ***		0.568 ***		0.567 ***		0.566 ***		0.566 ***		0.566 ***	
Change in R-Square (ΔR^2)			0.001 **		0.002 ***		0.001 **		0.000		0.000		0.000	

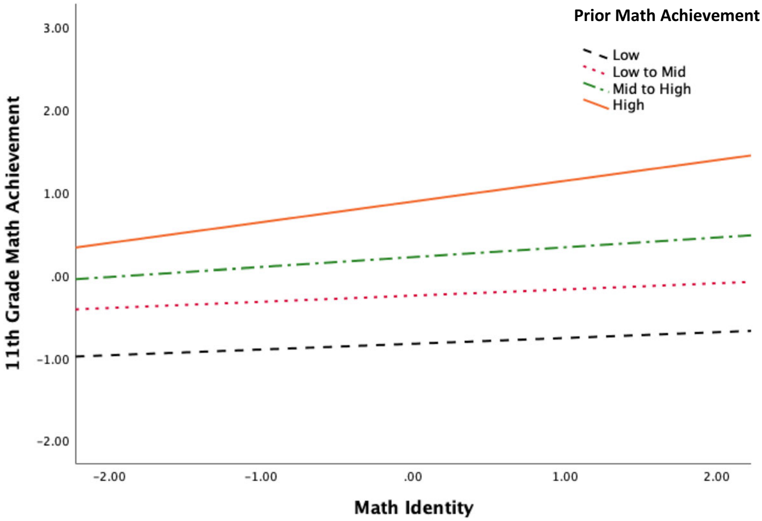

Fig. 1 Moderating effects of prior math achievement on relationship between math identity and 11th grade math achievement

achievement, Fig. 3 illustrates how this relationship differs for students with different levels of prior achievement. For students within the lowest prior math score quartile, the data suggests a slightly negative relationship between math interests and 11th grade math achievement. There are slight positive relationships between math interest and achievement for students in the low to mid and mid to high achievement quartiles. However, a relatively pronounced positive relationship between math interest and achievement exists for students with the highest level of prior math understanding. Accordingly, while students in the lowest achievement levels experience little or no benefit in their 11th grade

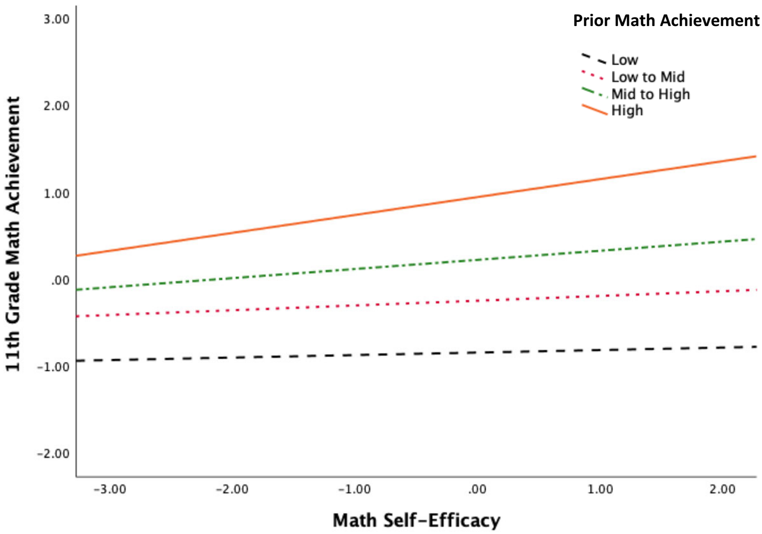

Fig. 2 Moderating effects of prior math achievement on relationship between math self-efficacy and 11th grade math achievement

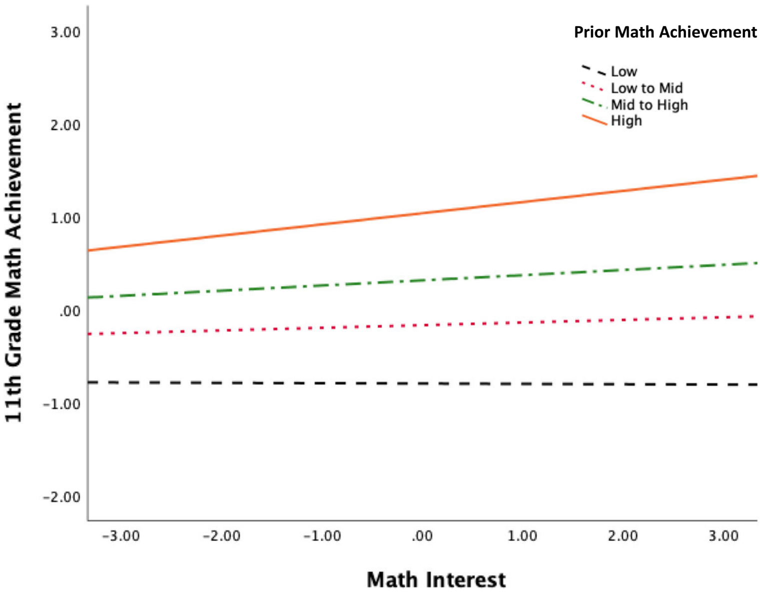

Fig. 3 Moderating effects of prior math achievement on relationship between math interest and 11th grade math achievement

math achievement from high levels of math interest, those with the highest prior math knowledge experience the greatest achievement returns from such an interest.

Discussion

Overall, the findings highlight how students' math-related psychological orientations and supports during earlier points in high school relate to their math achievement towards the end of their high school matriculation. Guided by the BRSAM, this study conceptualizes these factors as math-related strengths at the personal and social levels, and explores how these attributes and supports relate to a critical math outcome. This study also explores how those relationships may vary based upon students' prior levels of math achievement. The findings suggest that many of students' math-related MLS are positively associated with their math achievement, even after accounting for important demographic characteristics and prior math understanding. However, there are some important relationships worthy of further exploration and consideration. The following discussion outlines key aspects of these relationships, as well as implications for K-16 STEM education practice, public policy and areas of future research.

Math-Related Social Supports and Math Achievement: Implications for K-16 STEM Education Practice and Policy

The findings generally support the important role of students' math-related social supports in two areas: 1) their interactions with peers and highly-regarded adults about critical curricular decisions and 2) their involvement in math-related social groups.

In terms of math course-taking decisions, the findings suggest that general support in this arena is helpful for all students, and those potential benefits manifest equally regardless of students' prior math achievement. Accordingly, there are a number of potential implications that follow. Students consult with various individuals when making course decisions. However, school counselors are often one of the initial points of contact. Despite the important responsibility of these counselors in helping students make important educational decisions, these interactions need more attention at many schools. The demands placed on school counselors are commonly noted (Kim 2019; Lombardo 2018; Redwood 2019; Strauss 2013). Too many high schools have student to counselor ratios that stretch counselors too thin and disrupt their abilities to provide genuine academic advice and guidance to students—particularly those at under-resourced schools. While reprioritizing foci for existing counselors is one option to resolve current resource challenges, such an approach would not reduce the overwhelming demands on counselors' time and the various student needs where counselors could be instrumental. From a policy perspective, reframing school guidance counseling services and prioritizing sufficient counselor availability at the district and state levels could prove to be a more efficient response. Furthermore, an additional supply of guidance counselors may also help to facilitate increased interactions with teachers and families about optimal academic decisions. These additions would also benefit students ultimately and could have positive impacts on their success in math and other subject areas. Of course, this would require revamping or increasing educational budgets at the appropriate legislative level to ensure that such an initiative is properly funded, institutionalized and sustained.

In addition to math-related curriculum guidance from school counselors in particular, there may also be opportunities for college and K-12 systems to work across the schism that often exists between these educational sectors in order to facilitate students' math success. In doing so, college admissions representatives could work with counselors, teachers and possibly students to ensure alignment between course offerings, content, and sequences to better foster 1) competitive college admissions and 2) meeting learning expectations for potential STEM majors. This would help students to better understand what is needed to meet their developing collegiate goals and the appropriate path forward. While this study points to the importance of specific conversations pertaining to math courses with parents, peers and high school representatives, the establishment of a culture of support is important and also intimately tied to the broader information networks that students are then able to pull from when having these conversations about their academic plans. Expanding that network to include insight and expertise from key postsecondary representatives could help to broaden these networks in a way that will better prepare students for STEM success after high school.

In addition to support with math course selection, the findings also suggest a positive association between students' participation in math-related social support groups during high school (e.g., math clubs, summer programs, study group, etc.) and their 11th grade math achievement. Again, this positive relationship manifested equally regardless of students' prior level of math achievement. Moreover, the positive effects are apparent even after accounting for key demographic characteristics. While this positive relationship is encouraging, it is important to note that only a quarter of students in the sample indicated such participation at some point during their high school matriculation. Also, such participation was most prevalent among students with the highest level of prior math achievement (32% vs 22% to 24%). This underscores the potential benefits of targeted efforts to involve more students in these types of activities—particularly students without the highest prior achievement levels. For example, while a number of high schools currently conduct or participate in multi-school math competitions, such activities often reward students who can illustrate the greatest math achievement as opposed to the greatest growth in math understanding over a period of time. Reconceptualizing these competitions to reward growth could provide ripe opportunities to involve and engage more students who may have had prior challenges understanding math concepts.

State and local governments may also be instrumental in incentivizing schools to provide additional math supports. For example, policy initiatives could mandate financial support for math tutorial services targeting students in need of additional assistance. Also, partnerships between K-12 systems and higher education institutions may prove to be useful for establishing math-related social supports. Similar to federal foci on STEM education and student success (Brown et al. 2018; White House Office of Science and Technology Policy, 2018), state governments could prioritize these types of partnerships given the potential economic benefits from developing a robust future pool of STEM professionals. Such support could include funding the creation of K-20 STEM education programs that connect K-12 systems with public or private non-profit higher education institutions within the state. At the high school level, these programs could connect students, teachers and college faculty by creating student research partnerships between schools and local institutions. To maximize public resources, these research partnerships could focus on addressing STEM-related problems that pose an issue for the state and local communities. Teacher-led teams of students could work with STEM college faculty to use math and science concepts to help identify potential solutions to these challenges. Faculty members in STEM areas with an emphasis on practical applications and real-world problem-solving would make ideal candidates to facilitate such collaborations. Research areas could focus on issues concerning environmental preservation, communication systems, green energy or infrastructure among others. Moreover, earmarked research and development funding could be provided to institutions and schools that invest resources in establishing these relationships. These or similar collaborative efforts could be beneficial from multiple vantage points by expanding high school students' involvement in peer groups with a STEM focus; addressing broader needs that are important within the local and state contexts; and encouraging pathways and relationships across K-12 and postsecondary educational sectors.

Math-Related Personal Strengths and Math Achievement: Understanding Nuances in Key Relationships

While the findings generally note a positive relationship between math-related social supports and math achievement, the results concerning students' psychological orientations towards mathematics must be understood with some nuance that contextualizes these positive associations and acknowledges that these relationships may manifest differently for different students. In this study, some of the math-related personal attributes noted in existing math education practice and literature were positively associated with students' math achievement. Furthermore, these positive relationships manifested after accounting for important student background characteristics and prior math achievement. For example, identity has become a topic of common discussion for students at various educational levels (Aschbacher et al. 2010; Brotman and Moore 2008; Williams and George-Jackson 2014), and math identity is often emphasized to help foster students' math success (McGee and Pearman II 2014; Syed et al. 2011; Talafian et al. 2019). In this study, students' math identity was positively related to their math achievement; however, the nature of this positive relationship differed based on students' prior math understanding. Accordingly, improving students' identification with the subject could prove to be helpful for all students, but to varying degrees. Pedagogical approaches to increase student identity may include helping students to make connections between classroom content and real-life applications as previously discussed in the recommendation regarding high school-university student research partnerships. In addition to building STEM relationships, these partnerships could help students to envision themselves as STEM professionals. Other approaches may include allowing students to see themselves in math-related fields by exposing them to diverse STEM topics, and professionals in various industries where a strong math background is needed (SMASH Academy 2018; STEP n.d.).

Furthermore, normalizing the challenges that often occur when learning new math concepts and reframing students' experiences from a growth mindset perspective (Dweck 2006) would also be helpful for many students who have struggled previously in math classes. This would help these students to understand that being good at math is not necessarily a function of innate ability and (instead) conceptualize math as a subject where students with varying levels of prior achievement can ultimately be successful. Regardless of the approaches taken to increase students' math identity, it is important to note that improvements in math identification may not translate into improvements in math achievement similarly for students who begin with different levels of prior math understanding.

Similar to math identity, other math-related psychological attributes related to math achievement differently for different types of students. For example, students' interest in mathematics was not significantly related to their math knowledge in the main effects analysis. However, further investigation of moderating effects suggests a positive association between math interest and achievement for the highest achieving students, and a slightly negative relationship for the lowest achieving students. This information is insightful because many initiatives to promote STEM success focus on increasing students' interest in these subjects. While there are likely general benefits to increasing students' interests in math and other STEM fields, and this could ultimately lead to increased STEM participation, it is important to note that those interests may not relate directly and similarly to achievement outcomes for all students. However, there may be indirect relationships between students' interests and test scores that are mediated by other instrumental attributes. Nonetheless, math interest appears to have the greatest achievement benefits for students who have the highest prior math achievement. Understanding this nuance is critical for interventions that seek to improve students' math content understanding.

The results regarding math utility also highlight potential areas for future study. In this study, bivariate analysis suggests no significant relationship between students' conception of math utility and their math achievement. However, the regression results suggest that students' math utility of was negatively related to their math scores, ceteris parabis. While this study does not provide insight about why this negative association exists, perhaps students' conceptions of math utility are somehow related to other important characteristics that ultimately explain the noted relationship. For example, students' ideas about math utility may be connected to their experiences of math anxiety and the nature of that relationship my help to explain why those with higher utility generally have lower math scores. Additional studies are needed to explore these relationships and any underlying mechanism that may need to be better understood.

Similar to math utility, the association between math achievement and math self-efficacy must also be understood with some nuance informed by student's prior math knowledge. In these analyses, students having higher beliefs in their ability to do well in math was generally positively associated with their math achievement. However, an examination of this relationship moderated by prior math understanding illustrates that this positive relationship is not uniform for all students. In terms of increasing students' math scores, math self-efficacy appears to be most helpful for students who had the highest levels of prior math achievement. The magnitude of this relationship was only modestly positive for students with low levels of prior math understanding. Accordingly, while encouraging students' math self-efficacy beliefs are important, doing so appears to have optimal achievement returns when coupled with high levels of math training which can ultimately facilitate better math understanding. This underscores the need to emphasize increases in early math achievement while also focusing on non-cognitive math-related attributes to fully actualize the benefits of math self-efficacy. Accordingly, interventions that focus on both aspects of students' early math experiences, equally, are likely to be more successful than those that do not.

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Data Availability The data that support the findings of this study are openly available from the National Center for Education Statistics at https://nces.ed.gov/surveys/hsls09/hsls09_data.asp

Compliance with Ethical Standards

Conflict of Interest The corresponding author states that there is no conflict of interest.

References

Ahmed, W., Minnaert, A., van der Wer, G., & Kuyper, H. (2010). Perceived social support and early adolescents' achievement: The meditational roles of motivational beliefs and emotions. *Journal of Youth Adolescence, 39*(1), 36–46.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 47*(5), 564–582.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman and Company.

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78*(1), 246–263.

Bottia, M. C., Stearns, E., Mickelson, R. A., Moller, S., & Parker, A. D. (2015). The relationships among high school STEM learning experiences and students' intent to declare and declaration of a STEM major in college. *Teachers College Record, 117*(3), n3.

Bowman, P. J. (1985). Black fathers and the provider role: Role strain, informal coping resources and life happiness. In A. W. Boykin (Ed.), *Empirical research in black psychology* (pp. 9–19). Washington, DC: National Institute for Mental Health.

Bowman, P. J. (2006). Role strain and adaptation issues in the strength-based model: Diversity, multilevel, and life-span considerations. *The Counseling Psychologist, 34*(1), 118–133.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 45*(9), 971–1002.

Brown, K., Plozai, J., & Margetta, R. (2018). *NASA, National Science Foundation announce support for White House STEM engagement plan.* Retrieved from https://www.nasa.gov/press-release/nasa-national-science-foundation-announce-support-for-white-house-stem-engagement-plan Accessed April 6, 2020.

Burt, B. A., Williams, K. L., & Smith, W. A. (2018). Into the storm: Ecological and sociological impediments to black males' persistence in engineering graduate programs. *American Educational Research Journal, 55*(5), 965–1006.

Burt, B. A., Williams, K. L., & Palmer, G. J. (2019). It takes a village: The role of emic and etic adaptive strengths in the persistence of black men in engineering graduate programs. *American Educational Research Journal, 56*(1), 39–74.

Chatterjee, S., & Hadi, A. S. (2015). *Regression analysis by example*. Hoboken: Wiley.

Cheema, J. R., & Galluzzo, G. (2013). Analyzing the gender gap in math achievement: Evidence from a large-scale US sample. *Research in Education, 90*(1), 98–112.

Chubin, D. E., & DePass, A. L. (2015). *Understanding interventions that broaden participation in research careers: Translating research, impacting practice, vol. 7. Retrieved* from http://understanding-interventions.org/wp-content/uploads/2016/05/Understanding-Interventions-2015-Report.pdf Accessed April 6, 2020.

DePass, A. L., & Chubin, D. E. (2014). *Understanding interventions that broaden participation in research careers: Growing the community, vol. 6.* Retrieved from http://understanding-interventions.org/wp-content/uploads/2015/06/Understanding-Interventions-2014.pdf.

DePass, A. L., & Chubin, D. E. (2016). *Understanding interventions that broaden participation in research careers: Collaborative interventions, vol. 8*. Retrieved from http://understanding-interventions.org/wp-content/uploads/2017/10/UI-2016-Conference-Report.pdf Accessed April 6, 2020.

Dweck, C. (2006). *Mindset: The new psychology of success*. New York: Random House.

Dweck, C. S. (2007). Is math a gift? Beliefs that put females at risk. In S. J. Ceci & W. M. Williams (Eds.), *Why aren't more women in science?: Top researchers debate the evidence* (pp. 47–55). Washington, DC: American Psychological Association.

Eris, O., Chachra, D., Chen, H. L., Sheppard, S., Ludlow, L., Rosca, C., et al. (2010). Outcomes of a longitudinal administration of the persistence in engineering survey. *Journal of Engineering Education, 99*(4), 371–395.

Erturan, S., & Jansen, B. (2015). An investigation of boys' and girls' emotional experience of math, their math performance, and the relation between these variables. *European Journal of Psychology in Education, 30*(4), 421–435.

Fantuzzo, J., LeBoeuf, W., Rouse, H., & Chen, C. C. (2012). Academic achievement of African American boys: A city-wide, community-based investigation of risk and resilience. *Journal of School Psychology, 50*(5), 559–579.

French, B. F., Immekus, J. C., & Oakes, W. C. (2005). An examination of indicators of engineering students' success and persistence. *Journal of Engineering Education, 94*(4), 419–425.

Garcia-Melgar, A., & Meyers, N. (2020). STEM near peer mentoring for secondary school students: A case study of university mentors' experiences with online mentoring. *Journal for STEM Education Research*, 1–24. https://doi.org/10.1007/s41979-019-00024-9.

Goode, W. J. (1960). A theory of role strain. *American Sociological Review, 25*(1), 483–496.

Gottfried, M. A., & Plasman, J. S. (2018). From secondary to postsecondary: Charting an engineering career and technical education pathway. *Journal of Engineering Education, 107*(4), 531–555.

Griffith, D. M., Gunter, K., & Allen, J. O. (2011). Male gender role strain as a barrier to African American men's physical activity. *Health Education & Behavior, 38*(5), 482–491.
Hahs-Vaughn, D. L. (2005). A primer for using and understanding weights with national datasets. *The Journal of Experimental Education, 73*(3), 221–248.
Howard, T. C., & Reynolds, R. (2008). Examining parent involvement in reversing the underachievement of African American students in middle-class schools. *Educational Foundations, 22*(1–2), 79–98.
Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494–495.
Ingels, S. J., Pratt, D. J. Herget, D. R., Dever, J. A., Fritch, L. B., Ottem, R.,… Leinwand, S. (2013). *High School longitudinal study of 2009 (HSLS:09) base year to first follow-up data file documentation* (NCES 2014-361). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.
Jeynes, W. H. (2007). The relationship between parental involvement and urban secondary school student academic achievement: A meta-analysis. *Urban Education, 42*(1), 82–110.
Jones, B. D., Paretti, M. C., Hein, S. F., & Knott, T. W. (2010). An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans. *Journal of Engineering Education, 99*(4), 319–336.
Kim, T. E. (2019). *LA's school counselors strike back.* Retrieved from https://hechingerreport.org/las-school-counselors-strike-back/ Accessed April 6, 2020.
Kotok, S. (2017). Unfulfilled potential: High-achieving minority students and the high school achievement gap in math. *High School Journal, 100*(3), 183–202.
Liu, X., & Koirala, H. (2009). The effect of mathematics self-efficacy on mathematics achievement of high school students. *NERA Conference Proceedings*.
Lombardo, C. (2018). *With hundreds of students, school counselors just try to 'stay afloat'*. Retrieved from https://www.npr.org/sections/ed/2018/02/26/587377711/with-hundreds-of-students-school-counselors-just-try-to-stay-afloat Accessed April 6, 2020.
Mandara, J., Varner, F., Greene, N., & Richman, S. (2009). Intergenerational family predictors of the black-white achievement gap. *Journal of Educational Psychology, 101*(4), 867–878.
McGee, E., & Pearman II, F. A. (2014). Risk and protective factors in mathematically talented black male students: Snapshots from kindergarten through eighth grade. *Urban Education, 49*(4), 363–393.
Means, B., Wang, H., Wei, X., Iwatani, E., & Peters, V. (2018). Broadening participation in STEM college majors: Effects of attending a STEM-focused high school. *AERA Open, 4*(4). https://doi.org/10.1177/2332858418806305.
Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its influence on young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*(1), 60.
Murayama, K., Pekrun, R., Lichtenfeld, S., & Vom Hofe, R. (2013). Predicting long-term growth in students' mathematics achievement: The unique contributions of motivation and cognitive strategies. *Child Development, 84*(4), 1475–1490.
Nosek, B. A., Banaji, M. R., & Greenwald, A. G. (2002). Math=male, me=female, therefore math≠me. *Journal of Personality and Social Psychology, 83*(1), 44–59.
Pajares, F., & Miller, D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*(2), 193–203.
Pantziara, M. (2016). Student self-efficacy beliefs. In M. S. Hannula (Ed.), *Attitudes, beliefs, motivation, and identity in mathematics education: An overview of the field and future directions* (pp. 7–11). Heidelberg: Springer International Publishing.
Redwood, F. (2019). *Advocates: school counselor shortage hurts school safety.* Retrieved from https://nbc25news.com/news/local/advocates-school-counselor-shortage-hurts-school-safety Accessed April 6, 2020.
Skaalvik, E. M., Federici, R. A., & Klassen, R. M. (2015). Mathematics achievement and self-efficacy: Relations with motivation for mathematics. *International Journal of Educational Research, 72*, 129–136.
SMASH Academy (2018). *How SMASH academy works.* Retrieved from https://www.smash.org/programs/smash-academy/# Accessed April 6, 2020.
STEP (n.d.). *The Science and Technology Entry Program (STEP).* Retrieved from https://www.nyu.edu/admissions/undergraduate-admissions/how-to-apply/all-freshmen-applicants/opportunity-programs/pre-college-programs.html Accessed April 6, 2020.
Stinson, D. W. (2006). African American male adolescents, schooling (and mathematics): Deficiency, rejection, and achievement. *Review of Educational research, 76*(4), 477–506.

Strauss, V. (2013). *How big is the school counselor shortage? Big*. Retrieved from https://www.washingtonpost.com/news/answer-sheet/wp/2013/03/20/how-big-is-the-school-counselor-shortage-big/ Accessed April 6, 2020.
Strayhorn, T. L. (2010). The role of schools, families, and psychological variables on math achievement of black high school students. *The High School Journal, 93*(4), 177–194.
Syed, M., Azmitia, M., & Cooper, C. R. (2011). Identity and academic success among underrepresented ethnic minorities: An interdisciplinary review and integration. *Journal of Social Issues, 67*(3), 442–468.
Talafian, H., Moy, M. K., Woodard, M. A., & Foster, A. N. (2019). STEM identity exploration through an immersive learning environment. *Journal for STEM Education Research, 2*(2), 105–127.
The White House. (n.d.). *Education*. Retrieved from https://www.whitehouse.gov/issues/education/ Accessed April 6, 2020.
Thomas, S. L., & Heck, R. H. (2001). Analysis of large-scale secondary data in higher education research: Potential perils associated with complex sampling designs. *Research in Higher Education, 42*(5), 517–540.
Ting, S. M. R., & Man, R. (2001). Predicting academic success of first-year engineering students from standardized test scores and psychosocial variables. *International Journal of Engineering Education, 17*(1), 75–80.
Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk, 12*(3), 243–270.
U.S. Department of Education. (n.d.). *Science, technology, engineering and math: Education for global leadership*. Retrieved from https://www.ed.gov/stem Accessed April 6, 2020.
Usher, E. L., & Pajares, F. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research, 78*(4), 751–796.
Wang, X. (2013). Why students choose STEM majors: Motivation, high school learning, and postsecondary context of support. *American Educational Research Journal, 50*(5), 1081–1121.
Wang, M. T., & Degol, J. (2013). Motivational pathways to STEM career choices: Using expectancy–value perspective to understand individual and gender differences in STEM fields. *Developmental Review, 33*(4), 304–340.
White House Office of Science and Technology Policy (2018). *Charting a course for success: America's strategy for STEM education*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf
Williams, K. L. (2014a) *Financial impediments, academic challenges and pipeline intervention efficacy: A role strain and adaptation approach to successful STEM outcomes for underrepresented students* (unpublished doctoral dissertation). University of Michigan.
Williams, K. L. (2014b). Strains, strengths, and intervention outcomes: A critical examination of intervention efficacy for underrepresented groups. *New Directions for Institutional Research, 2013*(158), 9–22.
Williams, M. M., & George-Jackson, C. (2014). Using and doing science: Gender, self-efficacy, and science identity of undergraduate students in STEM. *Journal of Women and Minorities in Science and Engineering, 20*(2), 99–126.
Williams, K. L., Burt, B. A., & Hilton, A. (2016). Math achievement: A strain and adaptive strengths approach. *Journal for Multicultural Education, 10*(3), 368–383.
Williams, K. L., Mustafaa, F. N., & Burt, B. A. (2019). Black males and early math achievement: An examination of students' strengths and role strain with policy implications. *Journal of Women and Minorities in Science and Engineering, 25*(4), 325–352.
Zhang, G., Anderson, T. J., Ohland, M. W., & Thorndyke, B. R. (2004). Identifying factors influencing engineering student graduation: A longitudinal and cross-institutional study. *Journal of Engineering Education, 93*(4), 313–320.