Math achievement: a role strain and adaptation approach

Krystal L. Williams
Frederick D. Patterson Research Institute, United Negro College Fund, Washington, District of Columbia, USA
Brian A. Burt
Iowa State University, Ames, Iowa, USA, and
Adriel A. Hilton
Western Carolina University, Cullowhee, North Carolina, USA

Abstract

Purpose – This study aims to better understand how students' academic strains and multilevel strengths relate to their math achievement, with a particular emphasis on underrepresented students of color and girls given the need to broaden science, technology, engineering and math (STEM) participation for these groups.

Design/methodology/approach – National Education Longitudinal Study of 1988 data was used for a historical examination of the various student academic strains and multilevel strengths that relate to math achievement in high school. T-tests and chi-square tests were conducted to examine differences in strains and strengths across policy-relevant student subgroups. Ordinary least squares (OLS) regression was used to examine how students' strains and strengths related to their math achievement and the relative importance of each of these factors.

Findings – The findings suggest that both the academic strains and multilevel strengths that students' experience in middle school are related to their high school math achievement and the prevalence of these factors varies across different policy-relevant student subgroups. Furthermore, the relative importance of these factors on achievement differs.

Originality/value – Studies which focus on either students' academic challenges or their adaptive strengths fall short of a more nuanced discussion about how both factors relate to math outcomes. This study addresses this limitation and emphasizes that stakeholders who are interested in STEM diversity should consider holistic strategies for alleviating gender and racial/ethnic discrepancies in secondary math achievement.

Keywords Diversity, Adaptive strengths, STEM achievement, Student role strain

Paper type Research paper

Introduction

To broaden pathways into science, technology, engineering and math (STEM) professions, there is a growing need to identify strategies for improving student success in math and science for diverse populations. An expansive body of literature focuses on these issues and discusses outcomes such as major choice, persistence, STEM degree completion and entrance into the STEM workforce (Herzig, 2004; Hurtado *et al.*, 2008; Palmer *et al.*, 2011; Tsui, 2007). While each of these outcomes reflect critical points in the pipeline toward STEM careers, the foundation for postsecondary training in STEM is established during students' academic experiences in K–12. More specifically, students'

Journal for Multicultural Education
Vol. 10 No. 3, 2016
pp. 368-383

2053-535X
DOI 10.1108/JME-01-2016-0005

middle school mathematics experiences help to set the academic foundation for future STEM pathways in high school, college and beyond.

Given the importance of students' precollege math experiences on later outcomes, there has been an emphasis in higher education on better understanding math achievement in K–12 and the various factors that influence student success. Some research focuses on early student preparation issues and notes the importance of a rigorous curriculum to provide students with the academic exposure needed to advance in math and science sequences (Anderson, 2007; Berry, 2008; McGee and Pearman, 2014). Other studies note the importance of student support systems and various social and psychological factors in helping to promote successful outcomes (Erturan and Jansen, 2015; Jackson, 2013; Linder *et al.*, 2015; Martin, 2006; Ramirez *et al.*, 2015). While each of these studies provides useful insight about different elements that can hinder or encourage STEM success, they often fall short of a more nuanced discussion about how both students' challenges and their strengths operate in concert to affect successful outcomes.

Although students' academic challenges or strains can deter success in STEM, their various strengths may provide adaptive mechanisms for reducing or offsetting those negative effects (McGee and Pearman, 2014; Williams, 2014a, 2014b). An anti-deficit, holistic approach to identifying strength-based strategies for improving student success is important for all students. This is true especially for many underrepresented students in STEM because of the need to balance existing narratives that focus primarily on students' academic challenges in these subjects. Accordingly, this study explores how students' academic strains and their multilevel strengths relate to their STEM-related achievement, with a particular emphasis on underrepresented students of color and girls given the need to broaden STEM participation for these groups. This research focuses on a critical juncture in the STEM pipeline – the transition from middle school to high school – and math achievement given that this subject provides a foundation for many other STEM subjects. The following primary research questions are examined:

- *RQ1*. Are there racial and gender differences in students' early STEM-related academic role strains and multilevel strengths?
- *RQ2*. How do the academic strains and multilevel strengths that students experience in middle school relate to their STEM achievement in high school?
- *RQ3*. What is the relative importance of these strains and strengths on the outcome?

Theoretical framing

The concept of role strain has a long-standing history in various fields including sociology (Goode, 1960), psychology (Bowman, 1985, 2012, 2006) and education (Smedley *et al.*, 1993; Williams, 2014a, 2014b). Goode (1960) defines role strain as the difficulties that individuals may encounter with fulfilling the obligations associated with a particular role (i.e. parent, employee, etc). Research notes that the strains students experience can deter successful outcomes (Bowman, 2012). While the negative relationship between students' strains and college success are well documented, it is also important to note the role of students' strengths. Such an approach provides a more nuanced understanding of various factors affecting achievement in competitive STEM fields. The Bowman Role Strain and Adaptation Model (BRSAM) (2012) is a strength-based framework that acknowledges the importance of students' strengths and strains with regards to academic success. Building upon existing role strain literature, Bowman (2012) defines student role strain as the objective difficulties that individuals face in their role as students, as well as affiliated subjective responses to those objective difficulties. To illustrate this distinction, while students may have objective educational challenges such as low prior achievement on standardized tests, there may also be related subjective threats because of these difficulties such as academic discouragement. Both the objective and subjective aspects of strain can reduce student achievement in the future.

Because the BRSAM is strength-based, in addition to student role strain, it also notes the strengths that students can use at personal, community and institutional levels to facilitate positive outcomes (i.e. resilience, community and institutional support, etc). The framework notes that these multilevel strengths can encourage students to employ adaptive coping mechanisms when confronted with strain. Accordingly, to fully understand how students' strains relate to their academic achievement, it is essential to interrogate how their strengths operate within this context. Building upon this conceptual guidance, this study focuses on students' early objective and subjective academic strains in STEM and their related math achievement. In addition to academic student role strain, this study also examines the relationship between key noncognitive strengths and math achievement.

Literature review

Much of the existing literature regarding math achievement specifically, and STEM achievement in general, notes that students' early objective academic challenges can serve as strains or impediments to their future achievement in math. These objective challenges are generally measured by common metrics such as standardized test scores and grades. The research in this area often emphasizes student deficiencies in math and science and depicts students as being uninterested in learning in classrooms (Kane, 2012). These deficit-framed perceptions of achievement can have lasting effects on students. For instance, students' early educational performance in math and science can influence the type of academic track (e.g. remedial, college-prep, advanced placement) they are placed into upon entering high school. In addition, students' academic performance in K–12 has implications for the type of major they pursue upon entering college (Nicholls *et al.*, 2010, 2007). Thus, when students do not perform well in math at early points within their academic trajectories, they may have limited access to critical math and science preparatory courses in high school – the foundational courses needed for entrance into STEM majors in college (Herzig, 2004; Hurtado *et al.*, 2008).

In addition to objective academic challenges, there is also evidence that students' subjective appraisals toward mathematics are also important. For instance, students with a negative psychological orientation toward math can experience reduced or impeded math achievement. One such negative orientation that influences several achievement outcomes is math anxiety defined as "a feeling of tension, apprehension, or fear" toward mathematics (Ashcraft, 2002, p. 181). Math anxiety can play a role in students' math performance. For example, when students are nervous about their perceived math competence (Erturan and Jansen, 2015) and/or abilities to do well in math (i.e. math self-efficacy), their performance on math assessments (both classroom and standardized) can suffer (Ashcraft and Kirk, 2001; Meece *et al.*, 1990; Ramirez *et al.*, 2015). Empirical evidence shows the damaging long-term effects of math anxiety on students. Specifically, many students who consistently experience anxiety related to math also develop math avoidance behaviors (e.g. avoiding advanced-level math courses) (Erturan and Jansen, 2015). When students avoid taking advanced math courses, they become less competent in the subject, and less likely to choose STEM majors in college and career options which require extensive mathematical training (Meece *et al.*, 1990; Riegle-Crumb *et al.*, 2010).

While it is well documented that students' objective and subjective challenges in STEM can impede their achievement, a growing body of literature notes the role of students' strengths in promoting math achievement. This literature on students' strengths provides a compelling compliment to other studies that take a more deficit-orientation which emphasizes students' challenges. Students' strengths can manifest from various internal and external sources. Several interrelated psychological constructs intrinsically effect students' math achievement. First, how students feel about themselves (i.e. self-concept) – in the context of a being a mathematics learner – influences mathematical achievement (Erturan and Jansen, 2015). That is, when students feel confident about their abilities to do (Bandura, 1977; Fouad, 1995; Smith and Fouad, 1999) – and succeed at doing – math, they are more likely to achieve in math (Murayama *et al.*, 2013). Relatedly, students' mathematics enjoyment also influences math achievement. When students enjoy doing math, they develop particular adaptive strengths to persevere through academic setback, which promotes sustained achievement (Gottfried *et al.*, 2007). This ability to persist after academic disappointment, and to learn from and continue to improve one's math competency, is indicative of a value expectancy of math. Finally, when students believe that they are learning math content for a particular reason in the immediate and/or long-term future, they are further motivated to achieve in the subject (Erturan and Jansen, 2015; Jayaratne *et al.*, 2003; Linder *et al.*, 2015).

In addition to internal factors that promote students' math achievement, external factors such as academic support from parents and teachers can serve as strengths to foster academic success. Regarding families, parental support can come in various forms such as checking students' homework, being an active member in the school community and valuing education (Ahmed *et al.*, 2010). Parental support can also come in the form of student encouragement. In other words, when students believe (or perceive) they are being supported by their parents, they are more likely to achieve in math (Ahmed *et al.*, 2010). While the influence of parental support on academic achievement may differ by key demographic characteristics, such as students' gender, race and ethnicity, and parents' immigrant status (Sibley and Dearing, 2014), most research highlights the positive impacts of parental educational involvement. Students with involved parents tend to perform better than students with uninvolved parents (Stinson, 2008; Toldson, 2008). Furthermore, parental support has complementary psychological benefits. According to Ahmed *et al.* (2010), the strength of parental involvement reduced students' feelings of math anxiety, made students feel more confident in their abilities to perform at math, and increased students' math enjoyment. Thus, students' perceptions of external support in doing math, shapes students' self-concepts and beliefs about their abilities to succeed at math (Koutsoulis and Campbell, 2001) and influences their achievement in math.

Research also suggests that students' identification with a subject area helps to promote positive outcomes. Math identity is defined as a personal association between math and self (Nosek *et al.*, 2002). Achievement in math is as much about learning formulas as is it about developing an identity consistent with those who practice and do math (Anderson, 2007; Stinson, 2013; Varelas *et al.*, 2013). That is, the link between the learning of and doing math and science was related to teachers helping students to develop identities consistent with the practices of mathematicians and scientists. Such linkages have been shown to improve student outcomes along the K–16 pipeline (Nosek *et al.*, 2002; Syed *et al.*, 2011).

While existing studies note how students' strains and strengths can influence their outcomes independently, few studies examine how these mechanisms operate collectively (Williams, 2014a, 2014b). It is important to better understand how students' challenges relate to their STEM outcomes while also acknowledging their adaptive strengths. Similarly, the role of these strengths may differ within the context of strains. Given the limitation in existing scholarship regarding these relationships, this study expands current literature regarding early math achievement by noting how both STEM-related strains and multilevel strengths operate in concert and in relation to student success. Furthermore, this study seeks to better understand the relative importance of these different factors on early math achievement, which can influence students' future trajectories into STEM pathways and careers.

Methods

Sample and data

This study uses data from the National Education Longitudinal Study of 1988 (NELS: 88) – a nationally representative sample of eighth graders in the spring of 1988. The data includes information on various topics including students' experiences at school and home; education and occupational aspirations; and family and peer educational influences. Also, student achievement tests in reading, social studies, mathematics and science were administered in addition to the student questionnaire. While this data is historical, it remains the best nationally representative data set of eighth grade students in the USA and their educational experiences as they transition from middle school to high school. Our sample comes from the original NELS:88 study which used a two-stage probability design where 24,599 eighth grade students were randomly selected from 1,052 middle schools. While students were initially surveyed in the spring of 1988, follow up surveys were administered in 1990, 1992, 1994 and 2000. Given existing research which suggests that students' experiences in middle school and high school have lasting effects on their later opportunities in STEM (Nicholls *et al.*, 2010, 2007; Riegle-Crumb *et al.*, 2010), this study uses data from the base-year and first follow-up surveys to investigate how students' strains and strengths in middle school relate to their math achievement in tenth grade. The total sample for the study is limited to students with data for the base-year and first follow-up in NELS:88, and those who were in tenth grade when the first follow-up survey data were collected. The sample is also limited to students with scores on the tenth grade standardized test.

We used design effect adjusted weights in SPSS for all analyses to account for complex sampling design. Because design effect adjusted weights can result in underestimated standard errors (Hahs-Vaughn, 2005), we also used AM Software with appropriate weight, strata and cluster information to cross validate our results. The results may be generalized to the cohort of eighth grade students in the USA in 1988 who were also in tenth grade in 1990. For the unweighted sample, $N = 15{,}323$. For the sample with design effect adjusted weighting, $N = 3972$ which represents 2,533,679 eighth grade students in the USA.

Measures

This study examines how students' strains and strengths in middle school relate to their math achievement in high school to better understand the important role that each of these factors plays in helping to exacerbate or alleviate STEM pipeline issues. We use student academic stains and multilevel strengths indicators measured in eighth grade. The outcome, math achievement, is measured in tenth grade. Each of the measures is standardized to investigate their relative importance on math achievement in high school.

Academic student role strain. Academic student role strain is defined as the objective challenges that students encounter because of a lack of academic exposure and their subjective appraisal of those difficulties (Williams, 2014a, 2014b). This construct is operationalized using items concerning students' objective academic barriers and their subjective threats in response to these objective challenges. Students' objective academic barriers are measured by their prior math achievement challenges. More specifically, students' overall math proficiency was assessed in eighth grade and this information is used as an indication for objective academic student role strain in math. Because eighth grade math proficiency is based on students' middle school achievement, this measure also serves as an indicator of prior achievement in addition to a measure of strain. Prior studies suggest that students who mastered middle school math content were proficient at levels 2 and 3 (Hafner *et al.*, 1990). Accordingly, the original indicator for math proficiency is recoded such that students who did not meet minimum proficiency standards (i.e. those below level 2) are coded as 1 and those who did meet minimum standards (i.e. those a level 2 and above) are coded as 0.

In addition to objective academic role strain, subjective strain is tapped using a measure for students' math anxiety. This construct is operationalized by students' indication of whether or not they were afraid to ask questions in math class. Responses were provided on a four-point Likert scale from strongly agree to strongly disagree. The original measure is recoded such that students with greater values indicated higher levels of agreement with the statement.

Multilevel strengths. In this study, students' strengths are considered at both the family and personal levels. At the family level, the analyses employ a composite measure of family academic engagement. The items for this measure indicate the number of times that students spoke with their parents about selecting courses or programs at school, school activities or events and things studied in class. Responses to these questions were provided on a three-point Likert scale from "Not at All" to "3 or more times". Students indicated the number of times they discussed each of the aforementioned activities with parents since the beginning of the school year. The final family academic engagement measure was created by averaging students' responses across the individual items. The construct is tapped with a fair degree of internal consistency (Cronbach's alpha = 0.60).

With regards to personal strengths, this study examines how students' math engagement and math identity relate to their math achievement. Math engagement is measured according to whether or not students normally looked forward to mathematics class. Math identity is operationalized based on students' belief that math would be useful in their future. Responses to both survey questions were provided on a four-point Likert scale from "Strongly Agree" to "Strongly Disagree". The original items are recoded such that higher values represented higher levels of math engagement and identity.

Given the value of college ambitions in promoting successful outcomes in high school and beyond (Eccles *et al.*, 2004), students' early college plans are also included as a personal strength. The measure for early college ambitions is created based upon students' early postsecondary plans. More specifically, in eighth grade, students indicated their future post-secondary plans ranging from not finishing high school to plans for additional education after college. The original indicator is recoded so that students whose plans included a minimum of college attendance are coded as 1 and those with plans that did not include college attendance are coded as 0. Thus, the measure identifies students with early plans to pursue postsecondary education.

Background measures. In addition to students' academic strains and multilevel strengths, it was also important to account for key background characteristics that relate to math achievement. Accordingly, this study includes indicators of students' socio-economic status, sex and race/ethnicity. The original indicator for sex is recoded such that males are given a value of 1 and females a value of 0. With regards to race/ethnicity, in this study, the STEM achievement outcomes of traditionally underrepresented students in STEM (i.e. Hispanic, Black and American Indian/Native American) are compared to those of students who are White and Asian/Pacific Islander. Hence, the original data is recoded so that the former students are given a value of 1 and the latter a value of 0.

Analytic approach

To address research question 1, descriptive statistics were calculated to examine any differences in student academic role strain and multilevel strengths across policy-relevant student subgroups. Differences between males and females, and students who are underrepresented minorities in STEM and those who are White or Asian were considered given the general representation challenges for females and many minority groups in these fields. These comparisons are also important because of the need to bolster STEM success for certain student subgroups in order to diversify the pipeline of STEM professionals. T-tests and chi-square tests were conducted to determine if any differences were statistically significant. To address research questions 2 and 3, OLS regression was used to examine how students' early academic role strain and multilevel strengths related to their math achievement in high school and the relative importance of each of these factors. Given the continuous nature of the outcome, OLS regression was an appropriate analytic technique to employ (Chatterjee and Hadi, 2015). Additionally, each of the measures in these analyses was standardized to be able to examine effect sizes. The outcome (i.e. tenth grade math achievement), is also standardized.

Results

Academic student role strain and multilevel strengths for policy-relevant student subgroups

Table I provides information about the academic student role strains experienced by student subgroups, as well as their multilevel strengths. It also provides general

Key measures	Males (N = 1,969) Mean	SD	Females (N = 2,004) Mean	SD	p	White and Asian (N = 3,053) Mean	SD	Underrepresented minorities (N = 881) Mean	SD	p	All (N = 3,972) Mean	SD
Math achievement	51.32	10.02	50.89	9.60	n.s.	52.67	9.61	45.87	8.56	***	51.10	9.82
Academic student role strain items												
Math anxiety ([a])	1.94	0.73	1.99	0.79	~	1.95	0.75	2.01	0.82	n.s.	1.96	0.77
Objective math barrier	0.53	–	0.56	–	n.s.	0.50	–	0.73	–	***	0.54	–
Multilevel strengths												
Family academic engagement	2.34	0.51	2.47	0.47	***	2.43	0.49	2.31	0.52	***	2.41	0.49
Math engagement ([a])	2.64	0.89	2.55	0.88	**	2.53	0.87	2.81	0.90	***	2.60	0.88
Math identity ([a])	3.37	0.74	3.24	0.77	***	3.26	0.76	3.42	0.76	***	3.30	0.76
Early college ambitions	0.81	–	0.84	–	***	0.82	–	0.81	–	n.s.	0.83	–
Background												
Socio-economic status	0.00	0.74	−0.08	0.75	**	0.08	0.71	−0.45	0.72	***	−0.03	0.74
Male	–	–	–	–	–	–	–	–	–	–	0.50	–
Underrepresented minority	–	–	–	–	–	–	–	–	–	–	0.22	–

Notes: ~$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; [(a)] reverse coded

Table I.
Descriptive statistics by gender and race/ethnicity (weighted $N = 3.972$)

information about the overall sample employed in these analyses – a nationally representative sample of students who were in eighth grade in 1988 and in tenth grade two years later. As shown in Table I, 22 per cent of these students were underrepresented minorities in STEM and half were male. The majority of students in the study had early college ambitions. In fact, when asked in the eighth grade about their college plans, 83 per cent of students planned to attend college. While most students had post-secondary ambitions, many of them also had prior academic strains that could potentially hinder or detract from those plans – particularly as it relates to pursuing collegiate training in STEM. Over half of the sample (54 per cent) had limited proficiency in middle school math (i.e. objective math barrier).

While the previous statistics provide useful general information about students' academic strains and plans, the descriptive statistics disaggregated by student subgroups provide more nuanced information about the prevalence of these factors by race and gender. With regards to gender, males and females had similar math achievement levels in tenth grade, $t(3970) = -1.39$, n.s. Also, there was no statistically significant gender difference in the percentage of students with prior objective math barriers, X^2 (1, $N = 3566$) = 2.18, ns. However, there were slight gender differences in math anxiety experienced in eighth grade with girls reporting higher levels of strain, on average. This gender difference was moderately significant, t (3831) = 1.67, $p < 0.10$.

While males and females were similar in many ways with regards to their tenth grade math achievement and academic student role strain, these groups were quite different in relation to their multilevel strengths. On average, girls reported higher levels of family academic engagement, $t(3930) = 9.43$, $p < 0.001$, and a higher percentage of girls indicated early college ambitions, X^2 (1, $N = 3939$) = 12.66, $p < 0.001$. However, boys indicated higher levels of math engagement (t [3837] = −2.80 $p < 0.01$.) and math identity (t[3828] = −5.27, $p < 0.001$) in the eighth grade than their female peers.

Middle school racial/ethnic differences in math achievement, academic student role strain and multilevel strengths were also present. On average, underrepresented minorities in high school had standardized math scores that were lower than their peers who were White or Asian, $t(3932) = 18.93$, $p < 0.001$. Also, underrepresented minority students reported higher levels of academic strain in some regards. While students who were Black, Hispanic or Native American/American Indian reported similar levels of math anxiety in eighth grade as their peers who were White or Asian, $t(3796) = -1.62$, n.s., nearly three quarters of the aforementioned group experienced objective math barriers (i.e. prior math proficiency challenges), compared to 50 per cent of students who were White or Asian, X^2 (1, $N = 3533$) = 139.64, $p < 0.001$.
While underrepresented minorities in this study experience higher levels of math-related objective student role strain, they also reported greater eighth grade multilevel strengths in some respects. On average, underrepresented minority students indicated greater levels of math engagement, $t(3800) = -8.30$, $p < 0.001$ and math identity, $t(3793) = -5.18$, $p < 0.001$ than their White and Asian counterparts. However, White and Asian students reported higher levels of family academic engagement, $t(3894) = 6.26$, $p < 0.001$. No significant racial/ethnic differences emerged regarding students' early college ambitions X^2 (1, $N = 3902$) = 0.441, ns. On average, minority students were from lower SES families than their White or Asian peers, t (3932) = 19.88, $p < 0.001$.

Academic student role strain, multilevel strengths and math achievement

Table II provides information about the bivariate relationships between high school math achievement and each of the academic student role strain measures, along with the multilevel strengths. The table also provides correlations between the outcome and key background characteristics. Each of the measures for academic student role strain, and multilevel strengths is significantly related to high school math achievement in a manner that aligns with existing theory.

The findings suggest that each of the academic student role strain measures is negatively correlated with math achievement and each of the measures for students' multilevel strengths is positively related to the outcome. Although most of these measures share a small correlation with the outcome, one exception emerges for academic student role strain. Having objective math barriers in middle school is moderately and negatively correlated with STEM achievement in high school ($r = -0.67$, $p < 0.001$). Accordingly, students with objective math barriers generally had lower achievement levels than those without such barriers. It is also worth noting that, family SES has a moderate positive relationship with math achievement ($r = 0.43$, $p < 0.001$). Hence, higher SES students generally had higher math achievement than their lower SES peers.

The information in Table III allows for a more probing examination of the relationship between strains, strengths and achievement and the relative importance of each of these factors on the outcome while accounting for key background characteristics. Accordingly, it not only illustrates how strains are related to math achievement within the context of strengths (and vice versa), it also offers some insight about the magnitude of these relationships. In addition, Table III provides information about the degree to which each strain and strength measure explains the unique variance in students' tenth grade math achievement. A significant regression model was found ($F[3395] = 424.11$, $p < 0.001$), with an R^2 of 0.53 which suggests that the model accounts for 53 per cent of the variance in tenth grade math achievement. The model also

Academic student role strain and multilevel strengths	Math achievement ([a])	
Academic student role strain		
Math anxiety ([a])([b])	−0.13	***
Objective math barrier	−0.67	***
Multilevel strengths		
Family academic engagement ([a])	0.24	***
Math engagement ([a])([b])	0.07	***
Math identity ([a])([b])	0.07	***
Early college ambitions	0.29	***
Background		
Socio-economic status ([a])	0.43	***
Male	0.02	n.s.
Underrepresented minority	−0.29	***

Notes: ~ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; (a) variable is standardized (Mean = 0; SD = 1); (b) reverse coded

Table II. Correlations between academic student role strain, multilevel strengths and math achievement indicates that students' academic strains and multilevel strength are significantly related to the outcome even after accounting for important background characteristics. However, the magnitude of this relationship and the unique outcome variance explained differs across measures.

In terms of academic student role strain, both subjective and objective aspects of strain were negatively related to math achievement in tenth grade, ceteris paribus. In general, students with higher math anxiety in eighth grade also had lower math achievement in high school ($B = -0.03$, $p < 0.05$). Also, students with eighth grade objective math barriers had lower math achievement in tenth grade. Specifically, students with limited middle school math proficiency had high school math scores that were about one standard deviation below their peers who did not have such strain ($B = -1.06$, $p < 0.001$). This suggests that, although both objective and subjective academic barriers were negatively related to math achievement, students' objective barriers were more strongly related to the outcome than their subjective response to the objective barriers. In addition, while math anxiety explained less than 1 per cent of the unique variance in tenth grade math achievement, objective math barriers explained about 25 per cent of the variance in the outcome.

Students' multilevel strengths were also significantly related to their math achievement despite their strains and after accounting for background characteristics. While each of the multilevel strengths was positively related to the outcome, the magnitude of this relationship was largest for early college ambitions. Student with plans to attend college in the eighth grade had tenth grade math achievement scores that were over a quarter of a standard deviation higher than those without early college plans ($B = 0.28$, $p < 0.001$). Early college ambitions explained about 1 per cent of the unique variance in the tenth grade math achievement. Each additional measure of students' multilevel strengths explained less than 1 per cent of the outcome's unique variance.

Independent variable	B	SE	t	sr^2
Academic student role strain				
Math anxiety [a][b]	−0.03*	0.011	−2.46	0.001
Objective math barrier	−1.06***	0.022	−42.75	0.254
Multilevel strengths				
Family academic engagement [a]	0.06***	0.011	4.62	0.003
Math engagement [a][b]	0.05***	0.010	3.64	0.002
Math identity [a][b]	0.03*	0.010	2.40	0.001
Early college ambitions	0.28***	0.026	8.44	0.010
Background				
Socio-economic status [a]	0.19***	0.013	13.58	0.026
Male	0.04~	0.018	1.66	0.000
Underrepresented minority	−0.29***	0.026	−9.63	0.013

Notes: $R^2 = 0.53$; unstandardized coefficients reported; ~$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; [a] variable is standardized (Mean = 0; SD = 1); [b] reverse coded

Table III.
Regression analysis assessing the influence of students' eighth grade strains and strengths on tenth grade math achievement

Discussion

While these analyses are based on historical data, the results have implications concerning current needs to expand opportunities in STEM for diverse populations and to improve the pipeline into the STEM workforce. Although the strains and strengths that today's middle and high school students have may differ from earlier cohorts, recent evidence suggests that factors, such as anxiety (Ramirez *et al.*, 2015), early math proficiency challenges (Desilver, 2015), engagement (Sheldon *et al.*, 2010), identify (Cvencek *et al.*, 2011; Syed *et al.*, 2011) and college ambitions (Schneider, 2015) remain factors that influence student success. This study suggests that both the strains and strengths that students' experience in middle school are related to their later achievement in math and the prevalence of these factors varies across different policy-relevant student subgroups. With regards to academic student role strain, both math anxiety and objective math barriers experienced in middle school were negatively related to math achievement in high school. Furthermore, females reported slightly higher levels of math anxiety, and a higher percentage of underrepresented minorities experienced objective math barriers in middle school. It is worth noting that the magnitude of the relationship between students' objective math barrier in middle school and their tenth grade math achievement was the largest of all the strain and strength measures considered. Also, objective math barrier explained the greatest percentage of variance in the outcome. This underscores the importance of this factor in relation to math achievement – a critical subject area for further STEM success. Stakeholders (e.g. policymakers, educational practitioners, higher education administrators, etc.) who are interested in diversifying the STEM pipeline and increasing the number of women and people of color in these fields should consider strategies for addressing these strains in a multifaceted attempt to alleviate gender and racial/ethnic discrepancies in secondary math achievement. It is especially important that students' math achievement challenges prior to high school be addressed to improve their future achievement and progression in this subject.

While these analyses suggest that students' strains may have a detrimental impact on math achievement, their strengths may help to promote successful outcomes despite the strains. Each of the multilevel strengths considered in these analyses was positively related to student achievement. Among the strengths considered, early college ambitions had the largest relative importance on math achievement, and such plans were more prevalent among females compared to males. Females also indicated higher levels of family academic engagement. It is also worth noting that underrepresented minorities had higher levels of math engagement relative to White and Asian/Pacific Island students, as measured by excitement about attending math class. Underrepresented minorities also identified more strongly with the subject as measured by their indication of its future utility. Given the gender and racial/ethnic differences in multilevel strengths, these factors become additional strength-based elements that can be capitalized on to improve outcomes for females and underrepresented minorities in STEM.

To be sure, this study does not suggest that a strict focus on students' strengths can alleviate STEM pipeline representation issues. As the findings indicate, students' challenges in high school mathematics are largely driven by their under-preparation in middle school. However, we do note that both students' strains and their strengths are independently related to achievement. Therefore, we suggest that understanding students' strains and acknowledging their strengths provides a more holistic approach for improving outcomes. Any approach that focuses on one and not the other would lack the proper sophistication needed to understand and address the complexity of the STEM pipeline challenge.

The USA has historically served as a leader in higher education. However, the country is losing ground (Palmer *et al.*, 2011) and STEM fields are one of the major drivers of the nation's economic growth and development. Institutions along the K–16 pipeline (secondary to postsecondary) must actively participate in keeping the USA competitive in STEM fields. The United States Census Bureau (2012) projects that the USA will become a majority-minority nation by 2043. Given these forecasted demographic changes, it is crucial to acknowledge the leaky STEM pipeline for various student groups and to begin implementing critical interventions early in students' educational careers that address their academic challenges, capitalize on their multilevel strengths and prepare them for future STEM pathways.

References

Ahmed, W., Minnaert, A., van der Wer, G. and Hans, K. (2010), "Perceived social support and early adolescents' achievement: the meditational roles of motivational beliefs and emotions", *Journal of Youth Adolescence*, Vol. 39 No. 1, pp. 36-46.

Anderson, R. (2007), "Being a mathematics learner: four faces of identity", *The Mathematics Educator*, Vol. 17 No. 1, pp. 7-14.

Ashcraft, M.H. (2002), "Math anxiety: personal, educational, and cognitive consequences", *Current Directions in Psychological Science*, Vol. 11 No. 5, pp. 181-185.

Ashcraft, M.H. and Kirk, E.P. (2001), "The relationships among working memory, math anxiety and performance", *Journal of Experimental Psychology*, Vol. 130 No. 2, pp. 224-237.

Bandura, A. (1977), "Self-efficacy: toward a unifying theory of behavioral change", *Psychological Review*, Vol. 84 No. 2, pp. 191-215.

Berry, R.Q. III (2008), "Access to upper-level mathematics: the stories of successful African American middle school boys", *Journal for Research in Mathematics Education*, Vol. 39 No. 5, pp. 464-488.

Bowman, P.J. (1985), "Black fathers and the provider role: role strain, informal coping resources and life happiness", in Boykin, A.W. (Ed.), *Empirical Research in Black Psychology*, National Institute for Mental Health, Washington, DC, pp. 9-19.

Bowman, P.J. (2012), "Coping with provider role strain: adaptive cultural resources among Black husband-fathers", *Journal of Black Psychology*, Vol. 16 No. 2, pp. 1-21.

Bowman, P.J. (2006), "Role strain and adaptation issues in the strength-based model: diversity, multilevel, and life-span considerations", *Counseling Psychologist*, Vol. 34 No. 1, pp. 118-133.

Bowman, P.J. (2012), "Toward a strength-based assessment system: a comprehensive social psychological approach", in Bowman, P.J. and St. John, E.P. (Eds), *Diversity, Merit, and Higher Education: Readings on Equal Education*, AMS Press, New York, NY.

Chatterjee, S. and Hadi, A.S. (2015), *Regression Analysis by Example*, John Wiley and Sons, Hoboken, NJ.

Cvencek, D., Meltzoff, A.N. and Greenwald, A.G. (2011), "Math– gender stereotypes in elementary school children", *Child Development*, Vol. 82 No. 3, pp. 766-779.

Desilver, D. (2015), "US students improving – slowly – in math and science, but still lagging internationally", available at: www.pewresearch.org/fact-tank/2015/02/02/u-s-students-improving-slowly-in-math-and-science-but-still-lagging-internationally/ (accessed 25 March 2016).

Eccles, J.S., Vida, M.N. and Barber, B. (2004), "The relation of early adolescents' college plans and both academic ability and task-value beliefs to subsequent college enrollment", *The Journal of Early Adolescence*, Vol. 24 No. 1, pp. 63-77.

Erturan, S. and 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*, Vol. 30 No. 4, pp. 421-435.

Fouad, N.A. (1995), "Career linking: an intervention to promote math and science career awareness", *Journal of Counseling and Development*, Vol. 73 No. 5, pp. 527-534.

Goode, W.J. (1960), "A theory of role strain", *American Sociological Review*, Vol. 25 No. 1, pp. 483-496.

Gottfried, A.E., Marcoulides, G.A., Gottfried, A.W., Oliver, P.H. and Guerin, D.W. (2007), "Multivariate latent change modeling of developmental decline in academic intrinsic math motivation and achievement: childhood through adolescence", *International Journal of Behavioral Development*, Vol. 31 No. 4, pp. 317-327.

Hafner, A., Ingels, S., Schneider, B. and Stevenson, D. (1990), *A Profile of the American Eighth Grader: NELS: 88 Descriptive Summary*, National Center for Education Statistics, Washington, DC, available at: http://nces.ed.gov/pubs90/90458.pdf

Hahs-Vaughn, D.L. (2005), "A primer for using and understanding weights with national datasets", *The Journal of Experimental Education*, Vol. 73 No. 3, pp. 221-248.

Herzig, A.H. (2004), "Becoming mathematicians: women and students of color choosing and leaving doctoral mathematics", *Review of Educational Research*, Vol. 74 No. 2, pp. 171-214.

Hurtado, S., Eadan, M.K., Cabrera, N.L., Lin, M.H., Park, J. and Lopez, M. (2008), "Training future scientists: predicting first-year minority student participation in health science research", *Research in Higher Education*, Vol. 49 No. 2, pp. 126-152.

Jackson, C. (2013), "Elementary teachers' beliefs about African Americans in the mathematics classroom", *Journal of Mathematics Education at Teachers College*, Vol. 3 No. 2, pp. 90-96.

Jayaratne, T.E., Thomas, N.G. and Trautmann, M. (2003), "Intervention program to keep girls in the science pipeline: outcome differences by ethnic status", *Journal of Research in Science Teaching*, Vol. 40 No. 4, pp. 393-414.

Kane, J.M. (2012), "Young African American children constructing academic and disciplinary identities in an urban science classroom", *Science Education*, Vol. 96 No. 3, pp. 457-487.

Koutsoulis, M.K. and Campbell, J.R. (2001), "Family processes affect students' motivation, and science and math achievement in Cypriot high schools", *Structural Equation Modeling: A Multidisciplinary Journal*, Vol. 8 No. 1, pp. 108-127.

Linder, S.M., Smart, J.B. and Cribbs, J. (2015), "A multi-method investigation of mathematics motivation for elementary age students", *School Science and Mathematics*, Vol. 115 No. 8, pp. 392-403.

McGee, E. and Pearman, F.A. II (2014), "Risk and protective factors in mathematically talented Black male students: snapshots from kindergarten through eighth grade", *Urban Education*, Vol. 49 No. 4, pp. 363-393.

Martin, D. (2006), "Mathematics learning and participation as racialized forms of experience: African American parents speak on the struggle for mathematics literacy", *Mathematical Thinking and Learning*, Vol. 8 No. 3, pp. 197-229.

Meece, J.L., Wigfield, A. and 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*, Vol. 82 No. 1, pp. 60-70.

Murayama, K., Pekrun, R., Lichtenfeld, S. and vom Hofe, R. (2013), "Predicting long-term growth in students' mathematics achievement: the unique contributions of motivation and cognitive strategies", *Child Development*, Vol. 84 No. 4, pp. 1475-1490.

Nicholls, G.M., Wolfe, H., Besterfield-Sacre, M. and Shuman, L.J. (2010), "Predicting STEM degree outcomes based on eighth grade data and standard test scores", *Journal of Engineering Education*, Vol. 99 No. 3, pp. 209-223.

Nicholls, G.M., Wolfe, H., Besterfield-Sacre, M., Shuman, L.J. and Larpkiattaworn, S. (2007), "A method for identifying variables for predicting STEM enrollment", *Journal of Engineering Education*, Vol. 96 No. 1, pp. 33-44.

Nosek, B.A., Banaji, M.R. and Greenwald, A.G. (2002), "Math= male, me= female, therefore math≠ me", *Journal of personality and social psychology*, Vol. 83 No. 1, pp. 44-59.

Palmer, R.T., Maramba, D.C. and Dancy, T.E. (2011), "A qualitative investigation of factors promoting the retention and persistence of students of color in STEM", *The Journal of Negro Education*, Vol. 80 No. 4, pp. 491-504.

Ramirez, G., Chang, H., Maloney, E.A., Levine, S.C. and Beilock, S.L. (2015), "The relationship between math anxiety and math achievement in early elementary school: the role of problem solving strategies", *Journal of Experimental Child Psychology*, Vol. 141 No. 1, pp. 83-100.

Riegle-Crumb, C., Moore, C. and Ramos-Wada, A. (2010), "Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity", *Science Education*, Vol. 95 No. 3, pp. 458-476.

Schneider, B. (2015), "2014 AERA presidential address the college ambition program: a realistic transition strategy for traditionally disadvantaged students", *Educational Researcher*, Vol. 44 No. 7, pp. 394-403.

Sheldon, S.B., Epstein, J.L. and Galindo, C.L. (2010), "Not just numbers: creating a partnership climate to improve math proficiency in schools", *Leadership and Policy in Schools*, Vol. 9 No. 1, pp. 27-48.

Sibley, E. and Dearing, E. (2014), "Family educational involvement and child achievement in early elementary school for America-born and immigrant families", *Psychology in the Schools*, Vol. 51 No. 8, pp. 814-831.

Smedley, B.D., Myers, H.F. and Harrell, S.P. (1993), "Minority-status stresses and the college adjustment of ethnic minority freshmen", *Journal of Higher Education*, Vol. 64 No. 4, pp. 434-452.

Smith, P.L. and Fouad, N.A. (1999), "Subject-matter specificity of self-efficacy, outcome expectancies, interests, and goals: implications or the social-cognitive model", *Journal of Counseling Psychology*, Vol. 46 No. 4, pp. 461-471.

Stinson, D.W. (2008), "Negotiating sociocultural discourses: the counter-storytelling of academically (and mathematically) successful African American students", *American Educational Research Journal*, Vol. 45 No. 4, pp. 975-1010.

Stinson, D.W. (2013), "Negotiating the 'White male math myth': African American male students and success in school mathematics", *Journal for Research in Mathematics Education*, Vol. 44 No. 1, pp. 69-99.

Syed, M., Azmitia, M. and Cooper, C.R. (2011), "Identity and academic success among underrepresented ethnic minorities: an interdisciplinary review and integration", *Journal of Social Issues*, Vol. 67 No. 3, pp. 442-468.

Toldson, I.A. (2008), *Breaking barriers: Plotting the path to academic success for school-age African-American Males*. Congressional Black Caucus Foundation, Washington, DC.

Tsui, L. (2007), "Effective strategies to increase diversity in STEM fields: a review of the research literature", *The Journal of Negro Education*, Vol. 76 No. 4, pp. 555-581.

United States Census Bureau (2012), "US census bureau projections show a slower growing, older, more diverse nation a half century from now", Press release, available at: www.census.gov/newsroom/releases/archives/population/cb12-243.html (accessed 17 July 2016).

Varelas, M., Martin, D. and Kane, J. (2013), "Content learning and identity construction (CLIC): a framework to strengthen African American students' mathematics and science learning in urban elementary schools", *Human Development*, Vol. 55 Nos 5/6, pp. 319-339.

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, Michigan.

Williams, K.L. (2014b), "Strains, strengths, and intervention outcomes: a critical examination of intervention efficacy for underrepresented groups", *New Directions for Institutional Research*, Vol. 2013 No. 158, pp. 9-22.

Further reading

Stewart, E.B. (2006), "Family- and individual – level predictors of academic success for African American students: a longitudinal path analysis utilizing national data", *Journal of Black Studies*, Vol. 36 No. 4, pp. 597-621.

Wiggan, G. (2007), "Race, school achievement, and educational inequality: toward a student-based inquiry perspective", *Review of Educational Research*, Vol. 77 No. 3, pp. 310-333.

Corresponding author
Krystal L. Williams can be contacted at: krystal.williams@uncf.org