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Individuals' Math and Science Motivation and Their Subsequent STEM Choices and Achievement in High School and College: A Longitudinal Study of Gender and College Generation Status Differences

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Math and science motivational beliefs are essential in understanding students' science, technology, engineering, and math (STEM) achievement and choices in high school and college. Drawing on the Eccles' expectancy-value theory and Arnett's emerging adulthood framework, this study examined the relations among high school students' motivational beliefs in ninth grade and their STEM course taking and grade point average (GPA) throughout high school as well as their STEM major choice in college. In addition, we examined subgroup differences across (a) gender and (b) college generation status by testing mean-level differences as well as whether these relations between math and science motivational beliefs and STEM outcomes varied by gender and college generation status. Using nationally representative data from the High School Longitudinal Study (N = 14,040; M_{age} = 14; 51% female students), this study found that adolescents' math and science motivational beliefs at the beginning of high school were positively associated with STEM achievement and course taking throughout high school and college major choices 7 years later. The results showed that female and first-generation college students had lower math and science self-concept of ability and were less likely to pursue a STEM major in college. However, in most cases, the relations among indicators did not vary by gender and college generation status. This study provided insights for policymakers and practitioners that gender and college generation gaps in STEM are evident at least by the beginning of high school and carry forward to their STEM college choices.

Keywords: motivational beliefs, math, science, gender, first-generation college students

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Developing a globally competitive workforce in science, technology, engineering, and mathematics (STEM) fields is critical for sustainable economic growth in the United States (U.S. Congress Joint Economic Committee, 2012). Understanding what leads to the pursuit of a STEM major in college is critical in supporting a competitive STEM workforce. National reports have shown that subgroups of students who do not fit the mainstream STEM stereotype, such as female and first-generation college students, are underrepresented in STEM careers (Cataldi, Bennett, Chen, & Simone, 2018; National Science Foundation, 2019).

Adolescence and emerging adulthood are two pivotal developmental periods for students' STEM academic pathways (Arnett, 2007; Maltese & Tai, 2011). Scholars have argued that the developmental process of exploring one's identity and considering educational and occupational possibilities begins in adolescence and comes to the forefront during emerging adulthood (Arnett, 2000, 2014). In high school and college, students must make several academic choices that are consequential for their subsequent STEM outcomes into adulthood, such as which math or science courses to take in high school or whether to declare a STEM college major (Guo, Parker, Marsh, & Morin, 2015; Maltese & Tai, 2011). One key determinant of students' math and science achievement, course taking, and choices is students' math and science motivational beliefs (Wigfield et al., 2015).

This study investigates the developmental achievement-related motivational processes from adolescence through emerging adulthood. Drawing on Eccles' (2009) expectancy-value theory, we examine how students' math and science motivational beliefs (i.e., self-concept of ability and subjective task value) in ninth grade relate to their STEM course taking and grade point average (GPA) in high school as well as their STEM majors in college. Based on dimensional comparison theory (Möller & Marsh, 2013), we also tested the extent to which adolescents are more likely to pursue and achieve in STEM if they have high motivational beliefs in math and science. Moreover, this paper fills gaps in the literature by examining differences across (a) gender and (b) college generation status.

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Relations Between Math and Science Motivational Beliefs, Achievement, and Choices

Arnett's (2000, 2014) work poignantly demonstrates that although individuals may begin to grapple with their identity, including what they value and believe they are good at, and the associated educational and occupational choices during adolescence as Erikson (1993) theorized, individuals now have a prolonged psychological moratorium where they continue to explore these issues into emerging adulthood (i.e., 18–25 years of age). Individuals consider a variety of life possibilities and make enduring life decisions during emerging adulthood that have implications for their future career, marriage, and life paths into adulthood. Emerging adulthood is a distinct developmental period from both adolescence and adulthood due to five features: identity exploration, instability, self-focus, feeling in-between, and consideration of possibilities (Arnett, 2014). In fact, Arnett (2000) argues that identity exploration and consideration of possibilities are more pronounced in emerging adulthood compared to adolescence and that it is "the most heterogenous period of the lift course" (Arnett, 2007, p. 69). Though emerging adulthood is a distinct developmental period, Arnett (2000) agrees with life course theory (Elder Jr. & Rockwell, 1979) that developmental processes and decisions during emerging adulthood are, in part, driven by prior experiences in adolescence. Therefore, it is critical to understand the extent to which adolescents' motivational beliefs and achievements during high school relate to decisions during emerging adulthood, such as college major choice.

According to the Eccles' expectancy-value theory, individuals' achievement, persistence, and choices are determined in part by their self-concept of ability and subjective task value (Eccles, 2009; Wigfield et al., 2015). Self-concept of ability in expectancy-value theory is commonly defined as the self-evaluation of one's general ability in a specific domain (i.e., can I do the task?). Expectancy-value theory distinguishes different components of subjective task value (i.e., do I want to do the task?). In the current study, we focus on two subjective task values: intrinsic value, which is the enjoyment individuals gain from performing a task (i.e., interest), and utility value, which refers to how much the task fits within individuals' future plans.

According to expectancy-value theory (Eccles, 2009), students' domain-specific self-concept of ability and subjective task value in adolescence should directly shape their academic achievement and choices later during emerging adulthood. Within math, students' self-concept of ability and subjective task value are important predictors of their math outcomes within adolescence, including their math achievement (Wang, Degol, & Ye, 2015; Watt, Eccles, & Durik, 2006) and math course taking in high school (Simpkins, Fredricks, & Eccles, 2012; Wang, 2012). Although studied to a lesser extent than math, similar relations have emerged in science (Andersen & Ward, 2014; Simpkins, Davis-Kean, & Eccles, 2006). Though some findings suggest that adolescents' math and science motivational beliefs are positively related to their later STEM outcomes in emerging adulthood, including STEM major choices (Guo et al., 2015) and STEM career choices (Wang et al., 2015; Watt et al., 2012), less work exists on predicting these processes in emerging adulthood. Given Arnett's (2000, 2014) characterization of emerging adulthood as less stable, explorative, and a time to consider various possibilities, more research needs to examine the extent to which math and science motivational beliefs and achievements in adolescence predict their STEM choices in emerging adulthood.

Scholars have argued that understanding STEM performance and choices through individuals' motivational beliefs in a single domain is not sufficient to understand the development of adolescents' STEM pathways (Wang & Degol, 2017). Some researchers, for example, have argued that math is a gateway subject for adolescents' career aspirations in all STEM areas (Shapka, Domene, & Keating, 2006; Watt et al., 2017). Watt and colleagues' (2017) study argued that low math achievement or motivational beliefs early in high school leads to low performance and motivational beliefs in math-intensive STEM courses such as physical science and technology, which, in turn, pushes students away from STEM careers. However, the existing work largely has focused on the relations between math and subsequent STEM outcomes and have not integrated science into their analyses.

Existing work that does include both math and science, typically examines students' math and science motivational beliefs (a) in separate analyses (Andersen & Cross, 2014), or (b) a composite math–science score averaged across math and science (Garriott, Flores, & Martens, 2013; Leaper, Farkas, & Brown, 2012). Little is known about the relative impact of math and science motivational beliefs on students' STEM achievement and choices in high school or college (Wang & Degol, 2017). Without controlling for adolescents' science motivational beliefs, it is hard to test the hypothesis of whether math is the gateway to STEM careers. Examining the between-subjects processes of math and science motivational beliefs predicting STEM outcomes would provide a more comprehensive understanding of how math and science motivational beliefs shape STEM pathways.

Marsh (1986) developed the internal/external frame-of-references (I/E) model to study between-domain motivational beliefs. The I/E model posits that students' achievement in a specific domain has a positive effect on students' ability self-concepts in a matching domain (e.g., math achievement on math self-concept) and a negative effect on their self-concepts in a nonmatching domain (e.g., math achievement on verbal self-concept). Möller and Marsh (2013) extended the I/E model to dimensional comparison theory, which posits strong negative cross-domain effects in contrasting domains, like math and English, but much weaker or even positive effects for complementary domains, such as math and science. Recent studies have confirmed the dimensional comparison theory by examining the relations between students' achievement and ability self-concept of multiple domains. For example, Marsh and colleagues (2015) confirmed the negative effects on contrasting domains by testing the relations between achievement and ability self-concept of multiple academic domains, including native language, foreign language, history, biology, physics, and math. However, the positive effect of complementary domains is not well established in the literature. In addition to testing the complementarity of math and science motivational beliefs, we extend this work to test whether math and science motivational beliefs enhance the role of each other in predicting STEM outcomes.

Students' STEM course taking and achievement in high school is theorized to have a lifelong impact on their field of study in college and, consequently, their future occupations (Guo et al., 2015; Riegle-Crumb & King, 2010). However, studies on high school motivational beliefs predicting STEM pathways have often examined STEM outcomes measured during high school, such as their STEM occupational aspirations in high school (Wang, 2012; Watt et al., 2012). Although high school STEM aspirations positively relate to their actual STEM major choice in college (Guo, Wang, Ketonen, Eccles, & Salmela-Aro, 2018), the college years are a time of change and possibility (Arnett, 2000). It is unclear how the STEM motivations and achievements of high school students map onto their actual choices in emerging adulthood after individuals are able to explore more educational/occupational possibilities and their identity. To fully understand adolescents' STEM achievement and choices, we incorporated students' actual college majors during emerging adulthood and examined how their math and science motivational beliefs in adolescence and their high school STEM course taking and achievement predict their college majors (STEM vs. not).

Group Differences

The expectancy-value theory suggests that group differences can arise due to socializers' behaviors, contextual factors, and the broader cultural milieu (Wigfield et al., 2015). Moreover, the theory suggests that differences in stereotypes, socialization processes, and contexts can lead to (a) mean-level differences across groups, such as females having lower motivational beliefs than males, and (b) process-level differences, such as motivational beliefs being a stronger predictor for females than males. Therefore, in this study, we tested mean-level and process-level differences (a) across gender, and separately (b) across college generation status.

Gender Differences

According to expectancy-value theory (Eccles, 2009), gender role stereotypes are an aspect of adolescents' cultural milieu that affect their motivational beliefs and outcomes. Gender role stereotypes influence adolescents' math and science motivational beliefs and STEM outcomes through processes of the internalization of gender role development, gender role socialization, and the absence (or presence) of same-gender role models. Researches have shown that the gender gaps in math cognitive abilities begin to emerge, starting from mid-to-late adolescence (Lindberg, Hyde, Petersen, & Linn, 2010) consistently. Female adolescents tend to have lower math self-concepts of ability and subjective task value (Guo et al., 2015; Simpkins et al., 2012) and lower science motivational beliefs (Else-Quest, Mineo, & Higgins, 2013; Simpkins, Price, & Garcia, 2015) compared to male adolescents in high school. Female students are also less likely to enroll in the most advanced high school math and science classes (Nagy, Trautwein, Baumert, Köller, & Garrett, 2006; Watt, 2006), and less likely to choose some STEM majors or careers (Guo et al., 2015; Wang et al., 2015), even though they have similar if not higher math and science achievement than males in high school courses (Hyde, 2014; Nagy et al., 2006).

Despite consistent mean-level gender differences, the existing studies on process-level differences have yielded mixed findings. Guo and colleagues (2015) found that math utility value was a stronger predictor of math achievement for males than females among Australian high school students. In contrast, using samples from Australia, Canada, and the United States, Watt and colleagues (2012) found that utility value was a stronger predictor of adolescents' math-related career choices for females than males. Meanwhile, several studies have not found process-level gender differences on the relations between math self-concept and value with math and science outcomes in high school (Else-Quest et al., 2013; Priess-Groben & Hyde, 2017; Simpkins et al., 2012, 2015). Given the mixed results in the existing literature, it remains unclear whether gender moderates the relations between motivational beliefs and STEM outcomes, and if gender moderation emerges whether females or males would have the stronger relations as there is a study supporting males and one supporting females.

College Generation Differences

First-generation college students, who are the first in their family to attain a college degree, tend to have less enriching STEM-related experiences because of the disparities in their proximal environments, such as families and schools, compared to continuing-generation college students (Bui, 2002). Such group differences based on college generation status may become more salient at the end of high school and during their college years. First-generation college students, in general, have fewer parental educational resources, have lower college aspirations, and face more difficulty in terms of their college academic achievement, attendance, and graduation compared to continuing-generation college students (Stephens, Townsend, Markus, & Phillips, 2012; Wilson & Kittleson, 2013). Among college students, first-generation college students typically have lower achievement in college biology classes (Harackiewicz, Canning, Tibbetts, Priniski, & Hyde, 2016; Tibbetts, Harackiewicz, Priniski, & Canning, 2016) and are less likely to take higher-level math college courses compared to continuing-generation students (Chen & Carroll, 2005). However, no previous literature, to our knowledge, has systematically tested mean-level differences between first- and continuing-generation college students on these STEM indicators in high school.

Even less is known about the extent to which there are process-level differences based on college generation status. The relations between motivational beliefs and STEM outcomes could be different for first- and continuing-generation college students due to the differences in family resources and social support (Garriott et al., 2013; Gibbons & Borders, 2010). For example, it is possible that the adolescents' beliefs and achievements may be weaker predictors of emerging adults' college majors for first- compared to continuing-generation college students. College might expose first-generation college students to the wide variety of educational and occupational choices that they may not have been familiar with. Thus, there may be more exploration of possibilities and instability in educational choices from adolescence to emerging adulthood for first- compared to continuing-generation college students (Arnett, 2000). In contrast, motivational beliefs could be a stronger predictor of STEM outcomes for first-generation college students because they need higher motivational beliefs to overcome the challenges they face in STEM (Harackiewicz et al., 2016). It is important to understand whether motivational beliefs function similarly for first- and continuing-generation students. If motivational beliefs are important for first-generation college students in predicting their STEM major choices, interventions targeting first-generation college students' math and science motivational beliefs in high school could be very beneficial in supporting first-generation college students' STEM outcomes (Harackiewicz et al., 2016; Tibbetts et al., 2016).

The Current Study

Drawing on expectancy-value theory and dimensional comparison theory from adolescence into emerging adulthood (Arnett, 2000; Eccles, 2009; Möller & Marsh, 2013), we used longitudinal data with a large national representative sample of U.S. youth to examine the relations among high school students' math and science motivational beliefs (i.e., self-concept of ability and subjective task value), their STEM course taking and GPA in high school, and their major choices in college (STEM vs. not). The underlying conceptual model is presented in Figure 1. Throughout, we fully controlled for covariates that are associated with adolescents' and emerging adults' STEM outcomes including parent highest education, family income, gender, ethnicity, ninth-grade math achievement, and overall high school English GPA (Douglas & Attewell, 2017; Else-Quest et al., 2013; Simpkins et al., 2015).

We expected that math and science motivational beliefs would both uniquely and positively predict STEM outcomes in high school and college. We also hypothesized that math and science motivational beliefs would interact in predicting STEM outcomes so that having high motivational beliefs on both subjects would maximize the relation between motivational beliefs on STEM outcomes. Our second goal was to test differences across gender and college generation status. We hypothesized that female and first-generation college students would have lower motivational beliefs and lower STEM outcomes compared to their male and continuing-generation college counterparts. Given the mixed evidence for gender and that there is no prior literature on college generation status to our knowledge, we did not put forward a specific hypothesis; rather, our goal was to explore the process-level differences.

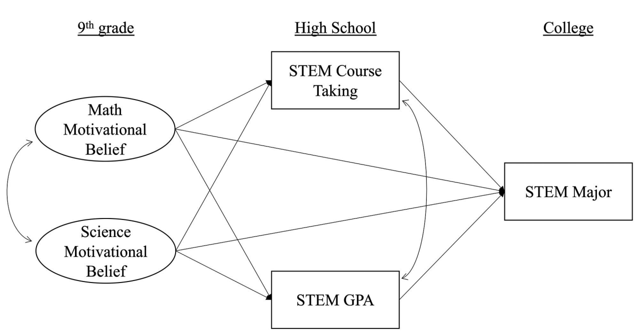

Figure 1. Conceptual model depicting the longitudinal relations between math and science motivational beliefs and STEM outcomes. Models were fully controlled for parents' highest education, family income, gender, ethnicity, ninth-grade math achievement, and high school English GPA. Ovals represent latent variables; rectangles are measured variables. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).

Method

Participants

Data were drawn from the High School Longitudinal Study (HSLS) of 2009. The High School Longitudinal Study of 2009 is a longitudinal study from the U.S. National Center for Education Statistics (NCES, 2016) that recruited a nationally representative sample of ninth graders across the United States (Ingels et al., 2011). Data were collected on 21,440 adolescents in 940 schools through a stratified, two-stage random sample design with primary sampling units defined as schools. In ninth grade, students on average were 14.42 years old, 51.46% were female students, 33.35% were prospective first-generation college students, and the median family income was between $55,000 and $75,000. The analytic sample comprised Caucasians (57%), Hispanic (15%), African American (9%), Asian (9%), and other race (10%, i.e., Native Americans, Pacific Islanders, and more than one race). The data used in this study were approved under IRB protocol at the University of California, Irvine, under the project title: Family Support of Math and Science: Examining an Untapped Source of Resilience for Diverse High School Students and IRB protocol number: HS#:2018–4349.

The analytic sample included 14,040 students who took both math and science classes in ninth grade and were enrolled in college. From the full sample of 21,440 participants, we excluded students who did not take math or science classes because they did not report math and science motivational beliefs in ninth grade (n = 4,690), and students who never enrolled in college as of February 2016, which was 3 years after high school (n = 2,710). We only included college students so that our comparisons focused on students who chose STEM majors and those who did not choose STEM. Comparisons of the analytic and the excluded samples are provided in Table 1. The analytic sample included students who had higher self-concept of ability (d = .25 and .23 for math and science respectively), higher math achievement (d = .59), higher high school English GPA (d = .56), and higher STEM outcomes (φ = .03 for STEM major and d = .34 and .57 for STEM course taking and GPA) than the excluded sample, whereas the subjective task value differences were small (d = .11 and .14 for math and science respectively). Also, families in the analytic sample had higher education levels (d = .51) and family incomes (d = .47). The analytic sample had fewer prospective first-generation college students compared to what was expected by chance (φ = −.23).

Measures

HSLS student survey in ninth grade was collected in fall 2009 and measured students' math and science motivational beliefs, including self-concept of ability and subjective task value. Transcript data of adolescents' high school course taking and GPA were collected in 2013, which was shortly after high school. College enrollment information was gathered in 2016. A complete list of items is provided in Table S1 in the online supplemental materials.

Self-concept of ability. Expectancy-value theory defines students' self-concept of ability as the extent to which students feel competent in a domain (Eccles, 2009; Wigfield et al., 2015). Four

Table 1
Comparisons Between Analytic and Excluded Samples

Measurements	Analytic sample					Excluded sample					*t*-test or Chi-square test	Effect size
	n	*M*	*SD*	Min	Max	*n*	*M*	*SD*	Min	Max		
Covariates												
Female	14,040	0.51	0.50	0.00	1.00	11,110	0.46	0.50	0.00	1.00	84.74***	.06[a]
White	14,040	0.57	0.50	0.00	1.00	9,200	0.46	0.50	0.00	1.00	244.46***	.10[a]
Hispanic	14,040	0.15	0.36	0.00	1.00	9,200	0.21	0.40	0.00	1.00	119.45***	−.07[a]
Black	14,040	0.09	0.29	0.00	1.00	9,200	0.15	0.36	0.00	1.00	203.32***	−.09[a]
Asian	14,040	0.09	0.29	0.00	1.00	9,200	0.09	0.29	0.00	1.00	0.45	−.00[a]
Other ethnicities	14,040	0.10	0.30	0.00	1.00	9,200	0.09	0.28	0.00	1.00	12.54***	.02[a]
First-generation college students	11,050	0.33	0.47	0.00	1.00	5,870	0.56	0.50	0.00	1.00	860.33***	−.23[a]
Parent highest education	11,100	3.55	1.54	1.00	7.00	5,890	2.79	1.36	1.00	7.00	31.67***	.51
Family income	11,100	5.11	3.16	1.00	13.00	5,850	3.71	2.58	1.00	13.00	29.15***	.47
Math achievement in ninth grade	14,040	53.11	9.72	24.10	82.19	7,410	47.35	9.66	24.02	79.53	41.19***	.59
High school English GPA	13,060	2.78	0.87	0.00	4.00	8,700	2.27	0.97	0.00	4.00	40.42***	.56
Ninth-grade motivational beliefs												
Math self-concept of ability	14,000	2.98	0.65	1.00	4.00	5,090	2.82	0.67	1.00	4.00	15.42***	.25
Math subjective task value	14,030	3.02	0.55	1.00	4.00	5,100	2.96	0.58	1.00	4.00	6.64***	.11
Science self-concept of ability	13,980	2.88	0.63	1.00	4.00	3,590	2.73	0.64	1.00	4.00	12.13***	.23
Science subjective task value	14,010	2.91	0.57	1.00	4.00	3,610	2.83	0.60	1.00	4.00	7.45***	.14
STEM outcomes												
STEM high school course taking	13,130	7.83	2.41	0.50	15.00	8,790	6.92	2.97	0.00	18.00	24.80***	.34
STEM high school GPA	13,090	2.62	0.86	0.00	4.00	8,740	2.11	0.94	0.00	4.00	40.97***	.57
STEM college major	8,820	0.25	0.43	0.00	1.00	2,740	0.21	0.41	0.00	1.00	13.81***	.03[a]

Note. Effect sizes are Cohen's *d* for continuous variables: small effect .10, moderate effect .30, large effect .80. Independent sample *t*-tests were used for continuous variables, and Chi-square tests were used for dichotomous variables. The *N*s were rounded to the nearest 10 according to the IES restricted-use data guidelines. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).
[a] Indicates effect sizes are phi coefficients: small effect .10, moderate effect .30, large effect .50.
*** $p < .001$.

items were used to measure students' math and science self-concept of ability in ninth grade (α = .90 for math and .88 for science; 1 = *strongly disagree*, 4 = *strongly agree*; e.g., "You are confident that you can do an excellent job on tests in this course").

Subjective task value. According to expectancy-value theory, students' subjective task value incorporates aspects of utility value (i.e., importance) and intrinsic value (i.e., interest; Eccles, 2009). Students' math and science utility value indicate the extent to which students think math and science are useful to their everyday life and future (Eccles, 2009; Wigfield et al., 2015). Three items of utility value were measured at ninth grade in each subject (α = .77 for math and .74 for science; 1 = *strongly disagree*, 4 = *strongly agree*; e.g., "What students learn in this course is useful for everyday life"). According to expectancy-value theory, intrinsic value is the enjoyment one gains from doing the task (Wigfield et al., 2015). Students reported their intrinsic value (i.e., interest) in math and science domain using three items in each subject (α = .77 for math and .81 for science; 1 = *strongly disagree*, 4 = *strongly agree*; e.g., "You are enjoying this class very much").

High school STEM course taking and GPA. STEM course taking was the total credits students earned in STEM subjects throughout high school (Ingels et al., 2011). One unit of credit was equivalent to a 1-year academic course taken one period a day, 5 days a week. STEM GPA was the cumulative GPA students earned in high school (Ingels et al., 2011), which ranges from 0 to 4 with a 4 representing the highest grade of A. STEM courses including math, science, engineering, and technology subjects were coded using the Secondary School Course Classification System: School Codes for the Exchange of Data (i.e., classes that begin with codes 02, 03, 10, 21; Bradby, Pedroso, & Rogers, 2007). One hundred and eight univariate outliers identified for the STEM course-taking variable were set to be equal to the 3 standard deviations above and below the mean.

STEM major choice in college. Students reported their first and second majors or fields of study for the undergraduate degree, including 4-year undergraduate degree and 2-year associate degree and certificate they were actively working on or had completed by February 2016. Students' college majors were coded using the U.S. Department of Education's Classification of Instructional Programs, 2010 edition (National Center of Educational Statistics, 2010), and then were categorized as STEM and non-STEM fields (Ingels et al., 2011). STEM major choice was a dichotomous variable of whether students' first or second major was math, science, engineering or technology (for a full list of STEM majors see Table S1 in the online supplemental materials).

Gender. Students reported their gender in ninth grade (1 = *female*, 0 = *male*).

First-generation college status. First-generation college status was a dichotomous variable indicating none of the students' parents had earned an associate's or bachelor's degree or above (1 = *first-generation college student*, 0 = *continuing-generation college student*).

Covariates. Parent highest education and family income, as well as student ethnicity, ninth-grade math achievement, and high school English GPA were incorporated as covariates in all of the models. Parents' highest education was the highest level of education achieved by either parent living in participants' home (1 = *less than high school*, 7 = *PhD/MD/Law/other high-level profes-*

sional degrees). Family income was reported by parents, which indicates students' family income from all sources in 2008 (1 = *less than or equal to $15,000*, 13 = *greater than $235,000*). Students' ninth-grade math achievement was a norm-referenced measurement of achievement that captured an estimate of students' achievement relate to the population (ninth graders of fall 2009; Ingels et al., 2011). Students' high school English GPA was the cumulative English GPA students earned throughout high school (0 = D, 4 = A).

Plan of Analysis

To test the conceptual model in Figure 1, we estimated one structural equation model for math and science self-concept of ability and a separate model for math and science subjective task value to avoid issues of multicollinearity. Students' math and science self-concept of ability and subjective task value were captured by latent variables using the fixed factor loading method (Little, 2013). The latent variables for math and science ability self-concepts were identified by the four self-concept of ability items described in the Method for each domain. The latent variables for math and science subjective task value were identified by the two mean subscales of utility value and intrinsic value based on theory (Eccles, 2009) and prior empirical work (Simpkins et al., 2015). We used the same process to create latent variables for math and science motivational beliefs. Parent's highest education, family income, ethnicity, and ninth-grade math achievement were included as controls for the constructs shown in Figure 1. In addition, high school English GPA was added to control for high school and college STEM outcomes; we also set it to covary with (but not predict) ninth-grade math and science motivational beliefs and controls because the motivational beliefs were collected in ninth grade and English GPA covered ninth to 12th grade.

We hypothesized that math and science motivational beliefs would interact in predicting STEM outcomes. A latent interaction term of math and science motivational beliefs was added to the model to test the interactive effects of math and science motivational beliefs on STEM outcomes using latent moderated structural equations approach.

We hypothesized that there would be mean-level differences in the focal constructs as well as process-level differences among constructs between (a) female and male students and (b) first- and continuing-generation college students. We examined the mean-level differences in the predictors and outcomes using the two-sample independent *t* tests. We conducted two sets of moderation analyses to determine whether the relations between motivational beliefs and STEM outcomes varied by gender and by college generation status. The test of measurement properties confirmed strong measurement invariance across gender and across college generation status (see Table S2 in the online supplemental materials). The multigroup analysis was done by, first, freely estimating paths in Figure 1 across groups. Then we constrained all paths and correlations shown in Figure 1 to be the same across groups to test whether there were group differences in the overall model. All model comparisons were conducted with the Satorra-Bentler scaled χ^2 difference test (Satorra & Bentler, 2001), because it is the recommended approach for models with MLR estimator (Muthén & Muthén, 2012). If the overall test of all paths was statistically significant across groups, then we followed up with comparisons of each path/correlation to identify which specific estimates varied across groups.

Structural equation models were estimated in Mplus 8.0 (Muthén & Muthén, 2012). All models estimated in this study were weighted to account for the nonresponse rate in the sampling process (WEIGHT = W4W1STU). Using TYPE = COMPLEX command, strata, and primary sampling unit (i.e., schools) variables were used to correct standard errors for the stratified design of data. Models were estimated using the robust maximum likelihood (MLR) estimator, which provides a robust estimation for non-normally distributed data, including our dichotomous indicator of STEM college major, when having a complex sample design. Missing data were handled by Full-Information-Maximum-Likelihood (FIML), which yields less biased estimates than traditional approaches such as listwise or pairwise deletion (Enders, 2010).

Robustness Checks

We included two robustness checks. First, because there is debate on whether scholars should estimate the missing data for participants who dropped out of longitudinal studies (Enders, 2010; Young & Johnson, 2015), we tested the robustness of our analyses using a subsample of students who were retained in the sample through college (n = 8,820). Comparisons of participants who completed the last round of data collection (n = 8,820) and those who did not (n = 5,220) are presented in Table S3 in the online supplemental materials. Students who completed the last round of data collection had higher self-concept of ability (d = .21 and .20 for math and science respectively), higher math achievement (d = .59), higher high school English GPA (d = .77), higher STEM outcomes (d = .54 and .78 for STEM course taking and GPA), higher parent education levels (d = .43) and family incomes (d = .30) than those who dropped out.

Second, we conducted a robustness check analysis with the multigroup analysis focusing on college generation. First-generation college students have traditionally been defined as students whose parents did not complete a bachelor's degree (Dika & D'Amico, 2016; Tibbetts et al., 2016). Because there may be differences among students whose parents have some college experience versus none, we conducted a robustness check on the multigroup analysis based on defining first-generation college students as students for whom neither of their parents had any bachelor's or associate's degree *experience*. Continuing-generation college students were students who had at least one parent who *started* or *earned* a bachelor or an associate degree. Approximately 1,360 adolescents had a parent who started a bachelor's or associate's degree but did not finish. Those students were moved from the first-generation college group to the continuing-generation college group in this robustness check analysis.

Results

Descriptive Statistics

Means, standard deviations, correlations, and partial correlations of focal variables are presented in Tables 1 and 2. Most students agreed on items of math and science motivational beliefs (M = 2.88–3.15). Within each subject, students' math and science self-concept of ability and subjective task value were moderately correlated (r = .36−.51). Across subjects, students' motivational

Table 2
Descriptive Statistics, Correlations (Below the Diagonal), and Partial Correlations (Above the Diagonal) Among Key Variables

Indicators	1	2	3	4	5	6	7	8	9
1. Math utility value	—	$.30^{***}$	$.19^{***}$	$.32^{***}$	$-.03^{*}$	$-.05^{***}$	$.02^{*}$	.01	.01
2. Math intrinsic value	$.45^{***}$	—	$.42^{***}$	$.12^{***}$	$.17^{***}$	$-.12^{***}$	.01	.02	−.01
3. Math self-concept of ability	$.36^{***}$	$.46^{***}$	—	$.06^{***}$	$-.05^{***}$	$.29^{***}$	.01	$.17^{***}$	$.03^{*}$
4. Science utility value	$.41^{***}$	$.27^{***}$	$.20^{***}$	—	$.41^{***}$	$.18^{***}$	$.06^{***}$	−.01	$.05^{***}$
5. Science intrinsic value	$.21^{***}$	$.27^{***}$	$.16^{***}$	$.51^{***}$	—	$.43^{***}$	$.05^{***}$	.01	$.03^{*}$
6. Science self-concept of ability	$.16^{***}$	$.19^{***}$	$.40^{***}$	$.38^{***}$	$.46^{***}$	—	$.03^{**}$	$.05^{***}$	$.08^{***}$
7. STEM high school course taking	$.07^{***}$	$.11^{***}$	$.17^{***}$	$.13^{***}$	$.11^{***}$	$.16^{***}$	—	$.19^{***}$	$.17^{***}$
8. STEM high school GPA	.01	$.16^{***}$	$.27^{***}$	$.09^{***}$	$.11^{***}$	$.22^{***}$	$.40^{***}$	—	$.13^{***}$
9. STEM college major	$.08^{***}$	$.09^{***}$	$.17^{***}$	$.13^{***}$	$.12^{***}$	$.18^{***}$	$.27^{***}$	$.21^{***}$	—
M	3.15	2.89	2.99	2.93	2.88	2.88	7.97	2.62	0.25
SD	0.62	0.69	0.65	0.62	0.72	0.62	2.22	0.81	0.43
Skewness	−.51	−.46	−.36	−.34	−.50	−.27	−.33	−.26	1.13
Kurtosis	.25	.06	.31	.30	−.05	.47	1.50	−.58	−.72

Note. Above the diagonal are the partial correlations controlling for parent highest education, family income, ethnicity, ninth-grade math achievement, and high school English GPA. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

beliefs were weakly to moderately correlated (r = .16−.41). STEM course taking and GPA were moderately correlated (r = .40). A correlation table with all correlations among predictor variables is provided in Table S4 in the online supplemental materials.

Relations Between Math and Science Motivational Beliefs, Achievement, and Choices

Self-concept of ability model. The model with math and science self-concept of ability predicting STEM outcomes was an excellent fit to the data according to model fit indices, $\chi^2(87)$ = 372.605, $p < .001$, CFI = .987, TLI = .978, RMSEA = .015, SRMR = .011 (See Table S5 in the online supplemental materials for all model coefficients). Items in the self-concept model evidenced significant loadings for both latent variables of math self-concept of ability: β = .78−.87, $p < .001$; and science self-concept of ability: β = .77−.83, $p < .001$. The focal path coefficients are shown in Figure 2a. Students' ninth-grade math self-concept of ability positively predicted their STEM course taking (β = .06, $p < .05$) and GPA (β = .11, $p < .001$) throughout high school after controlling for parents' highest education, family income, gender, ethnicity, ninth-grade math achievement, and high school English GPA. Only science self-concept of ability was uniquely and significantly associated with STEM college major choice (β = .08, $p < .001$). High school STEM course taking and GPA were positively associated with STEM major choice in college (β = .16 and .20, $p < .001$, respectively). Students who had taken more STEM classes and students who had a higher STEM GPA were more likely to go into STEM majors in college.

Subjective task value model. The model fit indices of math and science subjective task value predicting STEM outcomes model indicated a good fit to the data, $\chi^2(23)$ = 137.307, $p < .001$, CFI = .981, TLI = .932, RMSEA = .019, SRMR = .020 (See Table S6 in the online supplemental materials for all model coefficients). Items in the model evidenced significant loadings for the latent variables of math subjective task value including utility value and intrinsic value: β = .52 and .87, $p < .001$, respectively; and science subjective task value: β = .65 and .75, $p < .001$. The focal paths are shown in Figure 2b. Only math subjective task value uniquely predicted STEM course taking and GPA in high school (β = .07, $p < .05$, and β = .06, $p < .001$, respectively), whereas science subjective task value did not significantly predict each construct (β = .07, p = .09, and β = .01, p = .40, respectively). However, math subjective task value did not significantly predict STEM majors in college (β = .01, p = .70), whereas science subjective task value was positively associated with STEM major choice (β = .09, $p < .01$).

Interaction of Math and Science Motivational Beliefs

To test the interaction of math and science motivational beliefs, we added a latent interaction of math and science motivational beliefs to the self-concept of ability and subjective task value models in Figures 2a and 2b. The interactions predicted STEM course taking and GPA in high school and STEM major choice in college. The latent interaction term in the self-concept of ability model was statistically significant in predicting STEM majors (β = .05, $p < .001$), which indicated a multiplicative effect of math and science self-concept in predicting STEM major choices. In other words, for students who had high self-concept of ability in math, self-concept of ability in science contributed more positively to their STEM major choice and vice versa. The latent interaction did not significantly predict STEM course taking and STEM GPA in the self-concept of ability model (β = .006, p = .75, and β = .008, p = .31, respectively). When testing the latent interaction of math and science subjective task value on STEM outcomes, none of the interaction coefficients significantly predicted STEM outcomes of STEM course-taking (β = .05, p = .13), STEM GPA (β = .001, p = .92), and STEM major choice (β = .03, p = .43).

Group Differences

Gender differences. We hypothesized that female adolescents would have lower math and science motivational beliefs and STEM outcomes compared to male students. As shown in Table 3,

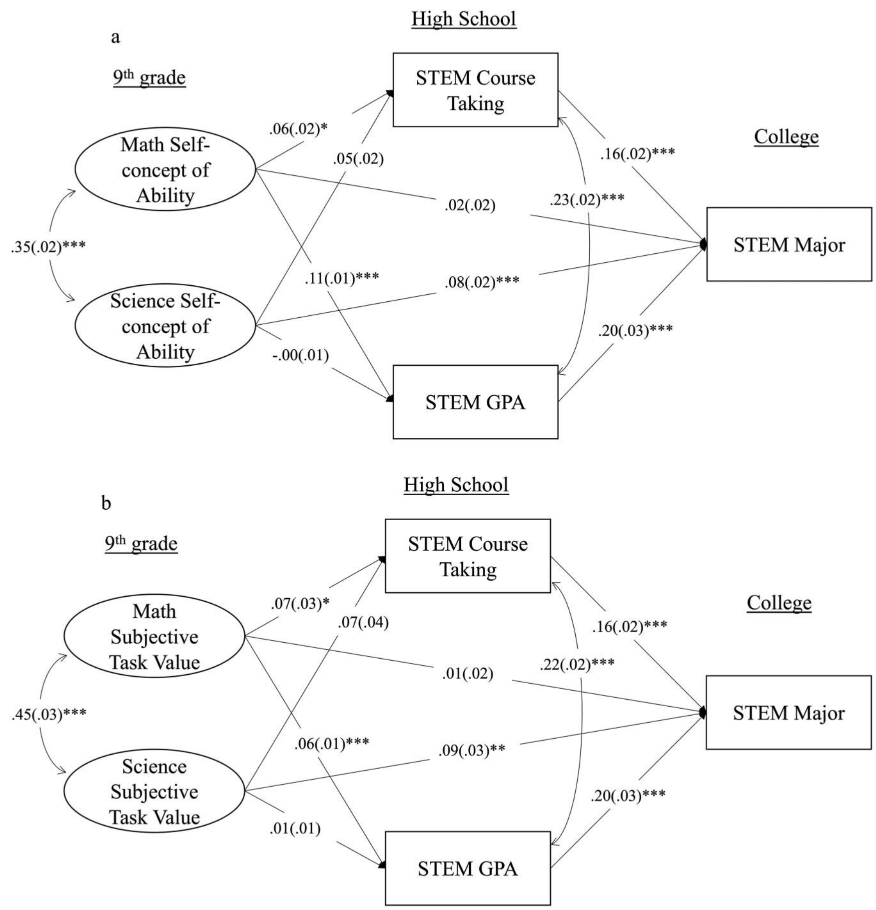

Figure 2. Standardized coefficients (and standard errors) of the predictive paths in the self-concept of ability (2a) and subjective task value models (2b). Models are fully controlled for parents' highest education, family income, gender, ethnicity, ninth-grade math achievement, and high school English GPA. $N = 14{,}040$. $^{*} p < .05$. $^{**} p < .01$. $^{***} p < .001$. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).

males overall had higher motivational beliefs in math and science than females; however, the effect sizes in differences were small for math and science self-concept of ability ($d = -.23$ and $-.28$, respectively). Although female adolescents, on average, had a higher GPA in their STEM high school classes (with a moderate effect size of $d = .30$), they were less likely to choose STEM college majors compared to males (with a moderate effect size of $\varphi = -.19$).

Multigroup analysis was used to examine gender differences in the relations between variables in Figures 3a and 3b. Model tests suggested that each model varied by gender: self-concept of ability model (Figure 3a), $\Delta\chi^2(10) = 22.449$, $p < .001$, and the subjective task value model (Figure 3b), $\Delta\chi^2(10) = 21.024$, $p < .001$. We followed up on these overall tests by examining whether each path in Figure 1 varied by gender. The post hoc analyses showed that there were significant differences across gender in the relation between STEM course taking and STEM major, for the self-concept of ability model (Figure 3a): $\Delta\chi^2(1) = 4.65$, $p < .05$, and for the subjective task value model (Figure 3b), $\Delta\chi^2(1) = 6.53$, $p < .05$. As shown in Figures 3a and 3b, STEM course-taking was more strongly associated with STEM major for female students in both models, $\beta = .18$ and $.19$, $p < .001$, than for males, $\beta = .13$ and $.11$, $p < .001$ in self-concept of ability and subjective task value models respectively. The results revealed that there were also gender differences in the relations between science subjective task value and STEM major, $\Delta\chi^2(1) = 7.06$, $p < .01$. Science subjective task value was positively associated with STEM major choices for male adolescents, $\beta = .14$, $p < .001$, but it did not predict for females, $\beta = .07$, $p = .34$ (Figure 3b). In the self-concept of ability model (Figure 3a), the relation between STEM GPA and STEM major was stronger for female students ($\beta = .25$, $p < .001$) than male students ($\beta = .16$, $p < .001$), $\Delta\chi^2(1) = 4.41$, $p < .05$. Finally, the correlation between math and science self-concept of ability was significantly different across groups, $\Delta\chi^2(1) = 3.93$, $p < .05$. It was stronger for female students, $r = .40$, $p < .001$ than male students, $r = .30$, $p < .001$ (see Figure 3a).

College generation differences. College generation differences analyses were conducted using a subsample of students who had college generation status data ($n = 11{,}050$). As shown in Table 3, first-generation college students had lower math and science ability self-concepts ($d = -.18$ and $-.21$, respectively), had lower STEM GPAs (with a moderate-to-large effect size of

Table 3
Mean, Standard Deviation, and Tests of the Differences of Ninth-grade Motivational Beliefs and STEM Outcomes Across Gender and College Generation Status

	Gender differences				College generation status differences			
Indicators	Female *M* (*SD*)	Male *M* (*SD*)	*t*-test or Chi-square test	Effect size	First generation *M* (*SD*)	Continuing generation *M* (*SD*)	*t*-test or Chi-square test	Effect size
Math self-concept of ability	2.91 (0.01)	3.06 (0.01)	−13.31***	−.23	2.93 (0.01)	3.04 (0.01)	−8.89***	−.18
Math subjective task value	3.01 (0.01)	3.03 (0.01)	−2.06*	−.03	3.04 (0.01)	3.02 (0.01)	2.14*	.04
Science self-concept of ability	2.79 (0.01)	2.97 (0.01)	−16.69***	−.28	2.81 (0.01)	2.94 (0.01)	−10.31***	−.21
Science subjective task value	2.89 (0.01)	2.90 (0.01)	−2.13*	−.04	2.90 (0.01)	2.93 (0.01)	−2.73**	−.05
STEM high school course taking	7.76 (0.03)	7.90 (0.03)	−3.38**	−.06	7.46 (0.04)	8.30 (0.03)	−18.10***	−.38
STEM high school GPA	2.75 (0.01)	2.49 (0.01)	16.52***	.30	2.40 (0.01)	2.86 (0.01)	−27.88***	−.58
STEM college major	0.16 (0.01)	0.33 (0.01)	324.11***	−.19[a]	0.19 (0.01)	0.27 (0.01)	49.82***	−.08[a]

Note. Effect sizes are Cohen's *d* for continuous variables: small effect .10, moderate effect .30, large effect .80. Independent sample *t*-tests were used for continuous variables, and Chi-square tests were used for dichotomous variables. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).
[a] Indicates effect sizes that are phi coefficients: small effect .10, moderate effect .30, large effect .50.
* $p < .05$. ** $p < .01$. *** $p < .001$.

$d = -.58$), took fewer STEM courses in high school (with a moderate effect size of $d = -.38$), and were less likely to choose STEM majors (with a small effect size of $\varphi = -.08$) than continuing-generation college students.

Multigroup models suggested there were differences across first- and continuing-generation college students in both the self-concept of ability model (Figure 4a) and subjective task value model (Figure 4b), $\Delta\chi^2(10) = 18.549$, $p < .001$, and $\Delta\chi^2(10) = 21.996$, $p < .001$, respectively. The post hoc analyses showed that there were significant differences between first- and continuing-generation college students in the relation of STEM GPA and STEM major, for the self-concept of ability model (Figure 4a): $\Delta\chi^2(1) = 6.73$, $p < .01$, and for the subjective task value model (Figure 4b), $\Delta\chi^2(1) = 5.29$, $p < .05$. As shown in Figures 4a and 4b, STEM GPA in high school was not associated with STEM college major for first-generation college students, but was a significant predictor of STEM college major for continuing-generation college students, $\beta = .22$ and $.23$, $p < .001$ in self-concept of ability (Figure 4a) and subjective task value (Figure 4b) models respectively. Also, the relation between science subjective task value and STEM major was significantly different between first- and continuing-generation college students, $\Delta\chi^2(1) = 8.69$, $p < .01$. Science subjective task value was a stronger predictor of STEM major for first-generation college students, $\beta = .16$, $p < .01$, than continuing-generation college students, $\beta = .08$, $p < .05$ (Figure 4b). Finally, the relation between STEM course taking and STEM major was significantly different across groups, $\Delta\chi^2(1) = 8.088$, $p < .001$. STEM course taking predicted STEM major more strongly for continuing-generation college students ($\beta = .20$, $p < .001$) than first-generation students ($\beta = .16$, $p < .001$) (Figure 4b).

Robustness Check Analyses

We conducted two sets of robustness check analyses. First, we reestimated the six models in Figures 2 through 4 using a subsample of participants who remained in the study through the last wave of data collection ($n = 8{,}820$). The results across these six models were very similar compared to the results presented in the paper using the full analytic sample (see Supplemental Material 1 in the online supplemental materials). There were three paths across in the models where findings changed in whether they were statistically significant versus not. These differences are described in detail in Supplemental Material 1 along with all of the results displayed in figures.

Second, we conducted a robustness check analysis with the multigroup analysis on college generation. We redefined first-generation college students as whose parents did not have any college experience or degrees (Supplemental Material 2). The robustness check analysis yielded similar results as the main analyses (see Supplemental Material 2 and Figure 4). There was one difference where a path changed in terms of statistical significance. In the original model (Figure 4b), math subjective task value positively predicted students' STEM GPA at the same level for first- and continuing-generation college students. In the robustness check, math subjective task value predicted STEM GPA in high school for first-generation college students, but not for continuing-generation students (Figure S4b).

Discussion

This study examined the links between two developmental periods, namely adolescence and emerging adulthood, by examining the relations between students' math and science motivational beliefs in ninth grade and their STEM outcomes over 7 years. Typically, students who felt confident in their math skills and valued math were more likely to take more STEM courses and have higher grades in STEM courses in high school, and students who have a higher science self-concept of ability and value would be more likely to pursue a STEM major in college. This study extended previous literature by linking both math and science motivational beliefs in ninth grade to students' STEM outcomes in high school and college. In addition to mean-level differences, we tested the process-level differences and found paths that functioned differently across gender. Little research, to our knowledge, examined the disparities in first- and continuing-generation college students' math and science motivational beliefs and STEM outcomes. Our research fills in the gap in the literature by testing both

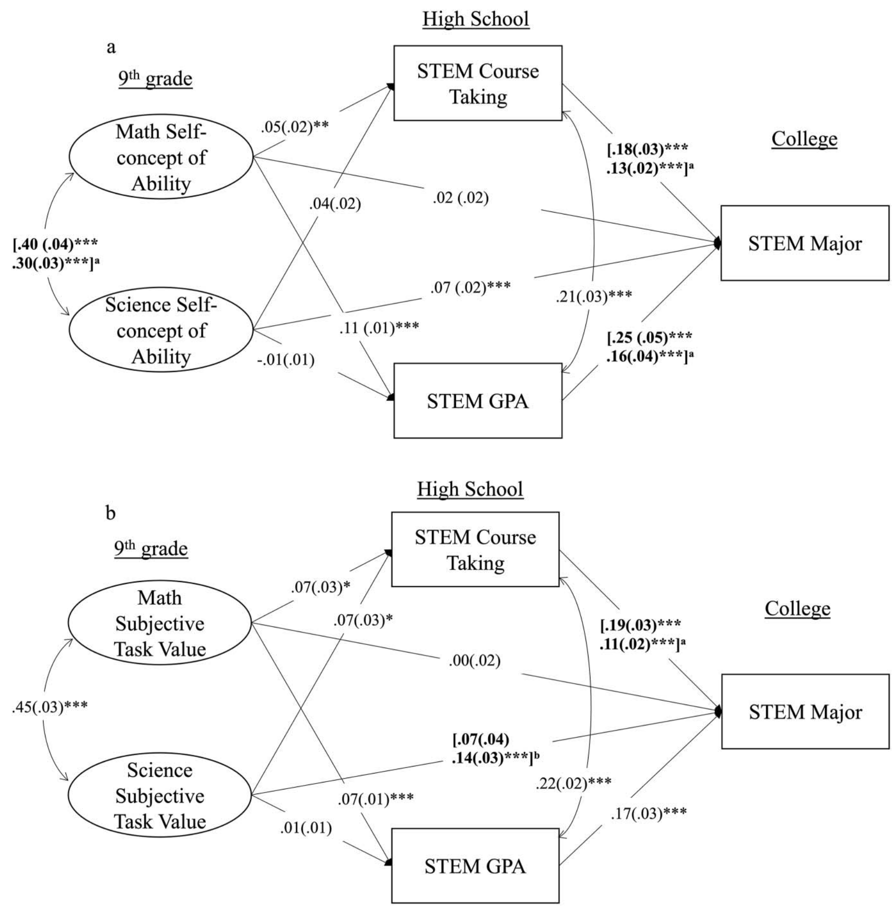

Figure 3. Standardized coefficients (and standard errors) of the predictive paths in the self-concept of ability (3a) and subjective task value (3b) models for female and male students (female coefficients on top). Paths that are significantly different between gender are bolded. The superscript letter noted the significance of the difference in paths: [a] indicates significance at $p < .05$ level, and [b] indicates significance at $p < .01$ level. Models are fully controlled for parents' highest education, family income, ethnicity, ninth-grade math achievement, and high school English GPA. $N = 14{,}040$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).

the mean-level and the process-level differences across gender and college generation status.

Relations Between Math and Science Motivational Beliefs, Achievement, and Choices

Aligned with expectancy-value theory (Eccles, 2009), dimensional comparison theory (Möller & Marsh, 2013), and work on emerging adulthood (Arnett, 2007, 2014), our results confirmed that both math and science motivational beliefs at the beginning of high school are important precursors of STEM achievement and choices in high school and college (Guo et al., 2015; Simpkins et al., 2006, 2012). Math motivational beliefs were directly related to STEM course taking and GPA in high school but not directly related to STEM major choice in college. These results supported the argument that "math is the gatekeeper" of students' subsequent achievement and choices in high school, especially in STEM (Shapka et al., 2006; Watt et al., 2017). Math motivational beliefs built the foundation for adolescents' achievement and choices beyond math in multiple STEM subjects in high school, which, in turn, predicted emerging adults' STEM major choices in college. Yet, adolescents' math motivational beliefs did not directly predict their college STEM major. Math motivational beliefs in high school may not be strongly connected to their college major as math may not only serve as a gateway to STEM majors, but to other majors as well. Given emerging adulthood is characterized as a time to explore one's identity as well as one's educational and occupational possibilities (Arnett, 2000, 2014), adolescents' math motivational beliefs may help support students' pursuit of a variety of majors in emerging adulthood.

In contrast, science motivational beliefs at the beginning of high school were directly related to students' STEM major choices in college, but not their high school STEM indicators. While math opened the gate for STEM, science kept and moved students further in the STEM pipeline. Students who were motivated in

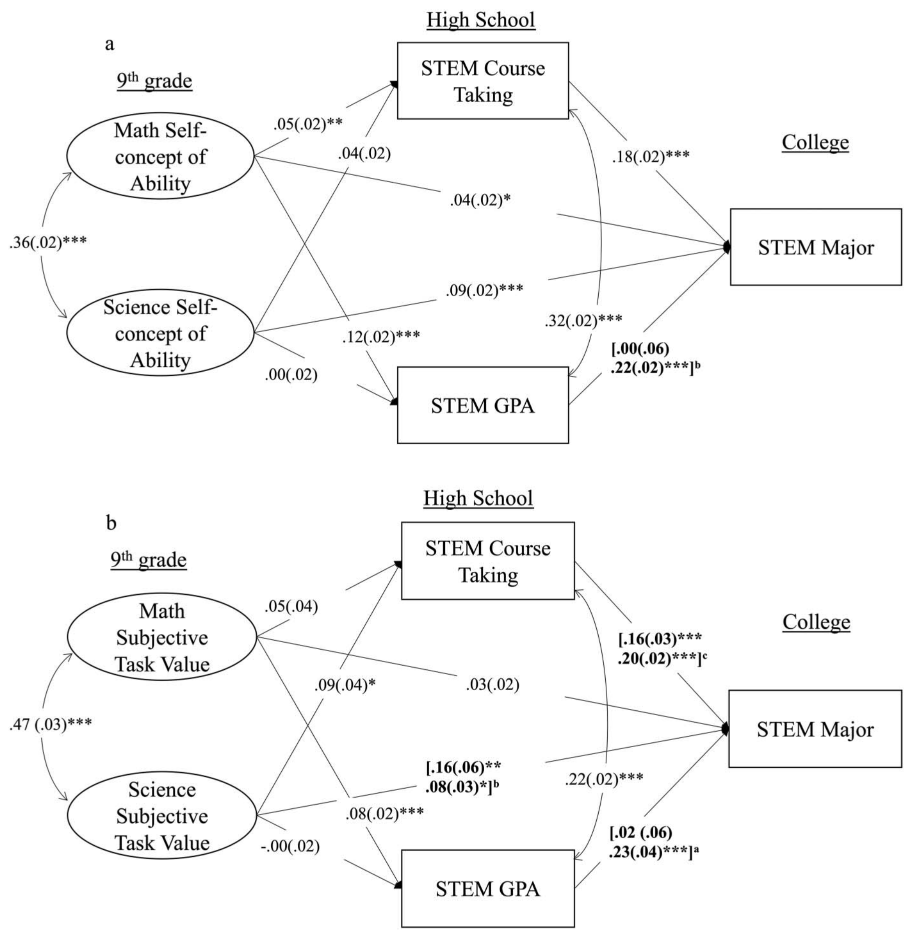

Figure 4. Standardized coefficients (and standard errors) of the predictive paths in the self-concept of ability (4a) and subjective task value (4b) models for first-generation college students and continuing-generation college students (first-generation college students' coefficients on top). Paths that are significantly different between the two college generations are bolded. The superscript letter noted the significance of the difference in paths: [a] indicates significance at $p < .05$ level, [b] indicates significance at $p < .01$ level, and [c] indicates significance at $p < .001$ level. Models are fully controlled for parents' highest education, family income, gender, ethnicity, ninth-grade math achievement, and high school English GPA. $n = 11{,}050$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. SOURCE: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09; National Center for Education Statistics, 2016).

science at the beginning of high school might be more determined to enroll in STEM majors in college and be more prepared when applying to STEM college majors. Moreover, although individuals' math skills may be utilized in a variety of STEM subjects, three of the four categories in STEM, namely science, technology, and engineering, all fall within the broad domain of science. Thus, science motivational beliefs may be stronger predictors of STEM majors in emerging adulthood as more STEM majors are within the broad domain of science versus the broad domain of math.

The fact that students' college major choice could be traced back to 7 years earlier highlighted the importance of developing a stable and viable identity during adolescence so that students could have more confidence to make enduring life commitments during emerging adulthood. Though individuals explore their identity and various possible life options well into emerging adulthood (Arnett, 2000, 2014), these enduring relations suggest interventions in adolescence might help set the stage for choices in emerging adulthood. Future interventions could consider supporting adolescents' math and science motivational beliefs simultaneously at the beginning of high school in order to prevent adolescents from dropping out of STEM at two points in the pipeline: high school and college. Traditional interventions on math and science cognitive skills should consider cultivating children's motivational beliefs by supporting children's self-concept of ability in math and science, fostering interest through hands-on activities, and helping children understand the value of math and science. For example, Gaspard and colleagues (2015), designed an intervention to enhance ninth-grade students' math value beliefs. They implemented a 1-hr intervention, either encouraging students to write an essay arguing how math connects to their current and future lives or having students read interview quotations of young adults describing the relevance of math and evaluate these quotations based on their personal relevance. They found that students who were in the intervention group gained significantly on their intrinsic and utility value compared to students in the control group.

One of the main foci of this study was to test the interactive role of math and science motivational beliefs on STEM outcomes. Contrary to our hypothesis, math and science motivational beliefs did not enhance the effect of each other in relation to STEM outcomes in most of the cases (five out of six). There was no strong evidence that math and science motivational beliefs interacted in predicting STEM outcomes, which means that the relations between math and science motivational beliefs and STEM outcomes were additive, where, as discussed earlier, math was more predictive of high school STEM indicators whereas science was more predictive of a college STEM major. Out of the six latent interaction paths, only math and science self-concept of ability interacted in predicting STEM major choices in college. The synergistic relation of math and science self-concept of ability in predicting STEM outcomes supported the positive cross-domain effects of math and science self-concept of ability as complementary subjects according to dimensional comparison theory (Möller & Marsh, 2013).

Group Differences

Gender differences. Consistent with our hypotheses, we found that female students tended to have lower math and science self-concept of ability and were less likely to enroll in STEM majors in college than male students, even though they earned higher grades than male students in STEM courses throughout high school. According to a meta-analysis on gender and math performance, the gender gap in math achievement has diminished over the past 20 years (Lindberg et al., 2010). Our study provides evidence that gender differences in STEM achievement during adolescence may have not only narrowed, but it could also be starting to reverse to favor female students. However, the gaps in motivational beliefs and choices persist during adolescence and emerging adulthood. Female students were less likely to pursue a STEM major even though they outperformed male students in STEM courses. One possible explanation could be that although male and female students took similar numbers of STEM courses in high school, female students were less likely to take advanced courses due to their low motivational beliefs in math and science (Maltese & Tai, 2011; Simpkins et al., 2015). Fewer and less advanced coursework in math and science may have cascading effects on female students' college STEM major choices.

We found that the gender differences in the process of motivational beliefs predicting STEM outcomes are infrequent and subtle in size. Out of the 18 paths we tested in two models, four were significantly different across gender. Thus, even though males tended to have higher math and science motivational beliefs than females, the relations between motivational beliefs and STEM outcomes functioned similarly across gender (Simpkins et al., 2012, 2015). Our results suggest that interventions on motivational beliefs to promote STEM outcomes could be equally effective for males and females in high school.

College generation differences. Aligned with our hypotheses, the results showed that first-generation college students tended to have lower math and science self-concepts of ability, took fewer STEM courses in high school, had lower a GPA in those classes, and were less likely to enroll in STEM majors during college. These patterns align with prior research in college suggesting the fact that first-generation college students are often at a disadvantage in the STEM pathways compared to continuing-generation college students (Harackiewicz et al., 2016; Wilson & Kittleson, 2013).

The relations between motivational beliefs and STEM outcomes were generally similar between first- and continuing-generation college students. Most (14 out of 18) of the paths tested in the models did not significantly differentiate between first- and continuing-generation college students. Among the few exceptions, we found that high school STEM course grades did not predict STEM majors in college for first-generation college students, whereas they were positively associated with continuing-generation college students' STEM major choices. Little is known about emerging adulthood processes among first- and continuing-generation college students. If first-generation college students are exposed to a newer, larger set of educational and occupational choices they had not considered before, there may be less continuity between adolescence STEM achievements and emerging adulthood STEM choices (Arnett, 2000, 2014). There may be a stronger alignment between adolescence and emerging adulthood among continuing-generation college students if they engage in more exploration during adolescence. More work is needed to understand students' knowledge of STEM career possibilities and the extent to which they have explored their identity during adolescence to test for whom there may be stronger alignment between these two developmental periods. Also, we found that science subjective task value was a stronger predictor of STEM majors for first- compared to continuing-generation college students. This finding implied that first-generation college students who regard science as important to them would be more likely to pursue STEM majors compared to continuing-generation college students. This finding provided insight for policymakers and practitioners who aim to narrow the college generation gap in STEM education into targeting first-generation college students' science values. Our results, along with prior studies, demonstrate the importance of science values in supporting first-generation college students' STEM achievement and choices (Harackiewicz et al., 2016).

Limitations and Future Directions

This study expanded the literature by examining the extent to which math and science motivational beliefs predicted STEM outcomes and group differences during adolescence and emerging adulthood. Nevertheless, limitations should be taken into consideration when interpreting the results. Quantitative data, such as those utilized in this study, have advantages in testing longitudinal relations and subgroup differences, but also provide less insight into the actual developmental processes. In order to get a comprehensive picture of how students make their STEM major choices, qualitative research is needed. It would be beneficial to understand the contextual factors that inform adolescents' STEM major choices, including the peers, the high school students were attending, and the college program they applied to. For example, students' motivational beliefs could be influenced by high school policies (e.g., course sequence policies, tracking), school climate, school composition (e.g., the percentage of potential first-generation college students), and their personal peer groups. Similar contextual influences could emerge at the college level, including different levels of support, especially for female and first-generation college students. Moreover, future qualitative studies could focus on the gender differences in the decision-making process of STEM majors; for example, why would math values relate to females' STEM major choices and science values relate to males' STEM major choices (Andersen & Ward, 2014).

Recent research shows that gender differences in individuals' motivational beliefs, performance, and choices vary across different science subjects. For example, female students have higher biology self-concepts and values, whereas male students report higher beliefs in physics (Nagy et al., 2006; Simpkins et al., 2015). Given that we found mean-level gender differences in math and science motivational beliefs, complementary research could differentiate among specific science and specific math subjects to disentangle the gender differences in adolescents' motivational beliefs in subdisciplines of STEM.

Due to the longitudinal nature of the dataset, we faced possible attrition bias in this study. Over the 7 years of data collection, 37.14% of the students in the analytic sample missed the last round of data collection in college. We handled missing data with current FIML techniques and ran a robustness check analysis using a subsample of students who did not drop out of the study in the last round of data collection. Given the current debates on how to best handle missing data in longitudinal studies (Enders, 2010; Young & Johnson, 2015), these analyses should be replicated in data sets with lower rates of attrition if possible.

Gender and college generational status gaps in STEM emerged in this study in ninth grade and these beliefs were predictive of their high school and college performance and choices, suggesting ninth grade might be a pivotal time for interventions. These ninth-grade gaps may have emerged earlier in individuals' educational pathways and last longer than emerging adulthood. More empirical work is needed to pinpoint when these gaps emerge and how far they persist to help inform earlier and additional opportunities for interventions.

Conclusion

This study examined the relations among ninth graders' math and science motivational beliefs with their STEM achievement and choices in high school and STEM major choices in college. The findings suggest that math and science motivational beliefs both play important but distinct roles in predicting STEM outcomes throughout high school and after the transition to college. Further, we found that students who believed they were competent in and valued math were more likely to have stronger STEM achievement and coursework in high school, whereas students who believed they were competent in and valued science were the ones most likely to pursue STEM majors in college. Although females and first-generation college students were often lower than their peers on these indicators, the overall process differences were subtle, meaning that similar precursors support the STEM achievements and choices for all students in high school and college. In summary, the present study provides substantively important findings for policymakers and practitioners seeking to promote equity in the STEM field of study.

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