ACT Research Report Series 2016 (8)

The Role of Academic Preparation and Interest on STEM Success

Justine Radunzel, PhD
Krista Mattern, PhD
Paul Westrick, PhD

Justine Radunzel is a principal research scientist in Statistical and Applied Research at ACT specializing in postsecondary outcomes research and validity evidence for the ACT test.

Krista Mattern is a director in Statistical and Applied Research at ACT specializing in the validity and fairness of assessment scores as well as more general issues in higher education such as enrollment, persistence, and graduation.

Paul Westrick is a research scientist in Statistical and Applied Research at ACT specializing in postsecondary outcomes research and validity evidence for the ACT test.

Acknowledgments

The authors thank Jeff Allen, Richard Sawyer, and Kyle Swaney for their helpful comments and suggestions on earlier drafts of this report.

 5940

Contents

Abstract

Research has shown that science, technology, engineering, and mathematics (STEM) majors who are more academically prepared—especially in terms of their mathematics and science test scores—are more likely to be successful across a variety of outcomes: cumulative grade point average (GPA), persistence in a STEM major, and ultimately earning a STEM degree. Research also shows, however, that many highly prepared STEM majors do not end up earning a STEM degree; likewise, some less academically prepared STEM majors persist and graduate with a STEM degree. These findings are consistent with a growing understanding that educational success is a product of a variety of cognitive and noncognitive factors. This study sought to identify student characteristics that, in addition to test scores, can be used to identify STEM majors who are likely to persist and ultimately complete a STEM degree. The study examined the relationship between students' chances of long-term success in college and their academic preparation and achievement, their expressed and measured interests in STEM, and their demographic characteristics.

Data on background characteristics, academic readiness for college, career-related interests, and college outcomes were obtained for nearly 76,000 STEM majors who enrolled as first-time entering students in fall 2005 through 2009 at 85 two- and four-year institutions. Academic readiness indicators included ACT® test scores, high school coursework, and grades earned. Students' interests in STEM fields were measured using their ACT Interest Inventory scores and their expressed major preference. Outcomes included annual cumulative GPA, persistence in a STEM-related field, and degree completion within six years. Student outcomes were tracked for at least four years and, where possible, across in-state institutions. Hierarchical regression models accounting for institution attended were used to estimate students' chances of succeeding in a STEM major. Results were evaluated by type of institution and STEM major category (Science; Computer Science & Mathematics; Medical & Health; and Engineering & Technology).

As expected, students who were better prepared in mathematics and science, as measured by achieving higher ACT scores, taking higher-level high school coursework, and earning higher HSGPAs in these subject areas, were more likely than those who were less prepared to earn a cumulative college GPA of 3.0 or higher, to persist in a STEM major through year 4, and to complete a STEM degree in four, five, or six years. Moreover, after statistically controlling for academic preparation and demographic characteristics, students with both expressed and measured interest in STEM were more likely to persist and complete a STEM degree than those with either expressed or measured interest only, as well as those with no interest in STEM. These findings were observed for each of the STEM major categories, though college success rates differed somewhat among STEM major categories. Additionally, gender and racial/ethnic differences in STEM persistence and STEM degree completion rates depended on STEM major category and type of institution.

These findings highlight the importance of helping students to have realistic expectations about the rigorous mathematics and science course requirements in STEM-related fields and to select a major that is aligned well with their academic skills and interests. Strong academic preparation for STEM fields needs to take place long before students enroll in college. Educators, advisors, and counselors can assist students in these areas by providing students with meaningful educational and career guidance that encourages them to explore personally relevant career options based on their own skills, interests, and aspirations.

Introduction

Policymakers continue to express concern about whether the United States will have sufficient numbers of college graduates to fill science, technology, engineering, and mathematics (STEM) occupations over the next decade in order to retain its competitiveness in the global economy (e.g., Langdon, McKittrick, Beede, Khan, & Doms, 2011; US Department of Labor, 2007). These concerns originate from recent US STEM-related statistics. For example, it has been reported that the US has one of the lower ratios of STEM to non-STEM bachelor degree completions in the world, fewer than 1 in 6 (National Science Board, 2014).[1] Additionally, STEM jobs are projected to grow 17% between 2008 and 2018, compared to only 9.8% for non-STEM jobs (Langdon et al., 2011). In response to these concerns, there have been recent calls for the US to produce more STEM graduates over the next decade to meet a projected one million STEM workforce shortfall (Executive Office of the President, President's Council of Advisors on Science and Technology, 2012). With a national focus on STEM success, new initiatives and programs are being increasingly implemented to promote STEM interest and participation among US students such as President Obama's "Educate to Innovate" campaign (White House, Office of the Press Secretary, 2009), and others (Government Accountability Office, 2012; Venkataraman, Riordan, & Olson, 2010).

Prior research has shown that students leave the STEM pipeline at various transition points along their education career. Furthermore, the percentage of students who declare a STEM-related major in college continues to lag behind what would be expected based on students' intentions. Specifically, of the roughly 1.9 million students in the 2015 ACT-tested high school graduate cohort, 40% expressed interest in majoring in a STEM field. An additional 9% of students who did not express an interest in STEM had measured interest in STEM based on their responses to the ACT Interest Inventory (ACT, 2015). In terms of actual STEM enrollment, national statistics suggest that fewer than 30% of students actually declare a STEM major in college (Chen, 2009; Chen & Ho, 2012). Additionally, the pool of prospective STEM workers continues to shrink as the majority of STEM majors do not earn degrees in STEM fields (Chen, 2013). Based on these statistics, it is clear that promoting awareness of STEM education is only part of what needs to be done. For example, identifying the characteristics of students who are most likely to persist and graduate with a STEM degree could inform targeted interventions to increase STEM participation in general and to promote STEM participation among those most likely to persist in a STEM field.

Research has begun to identify these characteristics. It has consistently been found that STEM majors who are more academically prepared—particularly in terms of their mathematics and science test scores—are more likely to be successful across a variety of outcomes: cumulative grade point average (GPA), persistence in a STEM major, and earning a STEM degree (e.g., Chen, 2013; Chen & Ho, 2012; Mattern, Radunzel, & Westrick, 2015; Shaw & Barbuti, 2010). Unfortunately, 50% or more of ACT-tested high school graduates with an interest in STEM do not meet the ACT College Readiness Benchmarks in mathematics and science (ACT, 2015). These benchmarks are the ACT mathematics and science scores associated with a 50% chance of success in first-year College Algebra and Biology courses, respectively (22 and 23, respectively; Allen, 2013).

[1] Degrees in the natural sciences and engineering make up 15.9% of the first university degrees awarded in the US. In contrast, the percentages for China, Japan, South Korea, Germany, France, Italy, the United Kingdom, and the Russian Federation are 43.7, 23.2, 35.6, 29.8, 26.9, 24.4, 22.4, and 16.5, respectively.

In addition, research suggests that academic readiness requirements for STEM are actually higher than those suggested by the ACT College Readiness Benchmarks, given that Calculus, instead of College Algebra, appears to be the typical first mathematics course of STEM majors (Chen, 2013; Mattern et al., 2015).[2] Among STEM-Quantitative majors who persisted through four years, Westrick (2014) found that the average ACT mathematics score for students earning a GPA of 3.0 or higher by semester was 28 across four years of college. In contrast, for students who earned semester GPAs of less than 3.0, the mean ACT mathematics score was 24 in the first semester and rose to 26 in the eighth semester (due in part to attrition of lower-scoring students). Higher STEM attrition rates have also been found among students attending institutions with less-selective admissions policies (Chen, 2009; Chen, 2013; Chen & Ho, 2012; Le, Robbins, & Westrick, 2014).

Higher STEM attrition rates and lower STEM degree completion rates have also been found for certain student demographic groups compared to those for their corresponding peers. These groups include female students (Beede, Julian, Langdon, McKittrick, Khan, & Doms, 2011; Gayles & Ampaw, 2014), underrepresented minority students (Anderson & Kim, 2006; Kokkelenberg & Sinha, 2010), first-generation students (Chen, 2009), and lower-income students (Chen, 2013). Among those with interests in STEM, students from these specific demographic groups also tend to be less likely to meet the ACT College Readiness Benchmarks in mathematics and science (ACT, 2015).[3]

That said, many academically prepared STEM majors do not end up earning a STEM degree; likewise, some academically underprepared STEM majors persist and graduate with a STEM degree. This is consistent with a growing body of literature that has found that educational success is a product of not only cognitive factors, but noncognitive factors (e.g., motivation, academic goals, and self-efficacy) as well (Mattern et al., 2014). In particular, theories of person-environment (P-E) fit provide a useful research paradigm for understanding students' selection and persistence in specific college majors (e.g., Dawis & Lofquist, 1984). The theory proposes that individuals seek out environments that are congruent with their own personal characteristics, including their abilities, values, and interests. Individuals who fit with their environment are also more likely to be satisfied and successful.

One of the predominant models of P-E fit used to explain how individuals choose careers and college majors is Holland's theory of vocational choice (1997). In this theory, both individuals and environments can be represented by six personality types: *Realistic*, *Investigative*, *Artistic*, *Social*, *Enterprising*, and *Conventional*. Empirical research supports this theory, as it has been shown that students' expressed and measured career interests play a role in choice of major and predict persistence and timely completion of a degree (e.g., Nye, Su, Rounds, & Drasgow, 2012; Rounds & Su, 2014), even beyond the effects of first-year academic performance, motivation, and other student demographic characteristics (Allen & Robbins, 2010).

With a focus on STEM, a recent study found that interest-major fit contributed incrementally beyond academic ability in predicting STEM major choice and STEM persistence to the second year (Le, Robbins, & Westrick, 2014). Another study found that high school students who planned to major in STEM were over three times more likely than those without such plans to complete a STEM degree (Maltese & Tai, 2011). Likewise, among bachelor's degree recipients, a study by Eagan, Hurtado, and

[2] Mattern et al. (2015) found that the ACT mathematics score associated with a 50% chance of success in Calculus was 27.

[3] The one exception was in Engineering & Technology, where females were more likely than males to meet the ACT College Readiness Benchmarks in mathematics and science.

Chang (2010) found that those who identified a STEM career goal during their freshman year were more likely to complete a STEM degree than those without such a goal (by 12 percentage points).

Building upon previous research, the purpose of the current multi-institutional study was twofold. The first objective was to identify pre-college factors beyond cognitive test scores that are useful for identifying STEM majors who are likely to earn a cumulative GPA of 3.0 or higher, persist in a STEM major, and ultimately complete a degree in a STEM-related field. Other student characteristics evaluated included additional measures of mathematics and science academic preparation (high school courses taken and grades earned), expressed and measured interests in STEM, and student demographic characteristics. Characteristics of the attending institution were also included, as success rates have been to show to vary by institution type and selectivity (Bowen, Chingos, & McPherson, 2009). The second objective was to examine whether there were any notable differences in STEM college success rates overall and by student characteristics among the STEM major categories included in this study. These categories included Science, Engineering & Technology, Medical & Health, and Computer Science & Mathematics.

Data

Sample

Data for this study included nearly 76,000 students from 85 two- and four-year institutions; these students took the ACT, enrolled in college as first-time entering students in fall 2005 through fall 2009, and declared a STEM major within two years of initially enrolling in college.[4,5] STEM majors comprised approximately 30% of the total sample of ACT-tested students at these partnering institutions.[6] Student outcomes were tracked for at least four years at the initial institution attended, and where possible, across in-state institutions. Institutions provided students' declared majors over time by reporting a six-digit Classification of Instruction Program (CIP) code for each term enrolled.[7] These major CIP codes were used to identify STEM majors (based on fall and spring terms within the first two years of initially enrolling in college). Seventy-nine percent of STEM majors declared a STEM major during their first fall term, 14% had switched from undeclared to STEM over the two-year period, and 7% had switched from non-STEM to STEM.[8] Many definitions of STEM exist; the current study employed ACT's definition of STEM (2014b), which categorized STEM majors into four clusters based on their declared majors: Science, Computer Science & Mathematics, Medical & Health, and Engineering & Technology.[9]

[4] For all but one institution, outcome data were provided for at least three freshman cohorts that had four or more years of follow-up. The exceptional institution provided outcome data for two freshman cohorts.

[5] STEM majors were identified within the first two years of initial enrollment due to the relatively high percentage of students who were undeclared during their first year of college (28% and 46% among students initially enrolling in a four-year institution and two-year institution, respectively).

[6] The percentage was 33% for students who began at a four-year institution and 24% for the students who began at a two-year institution.

[7] More detailed information about the National Center for Education Statistics (NCES) 2010 CIP codes is available at nces.ed.gov/ipeds/cipcode/Default.aspx?y=55.

[8] College success rates among these groups were comparable.

[9] Given the lack of consistency among the various STEM definitions being currently employed, ACT (2014b) conducted a comprehensive review of the literature and provided a refined definition of STEM. One distinction of ACT's definition is that it excludes social/behavioral sciences such as psychology and sociology (Green, 2007). To learn more about which majors and occupations are included in ACT's definition of STEM, refer to the original report (ACT, 2014b). The CIP codes included for each STEM major category are shown in Appendix A, Table A1.

The sample for the study does not represent students or institutions nationally. A large majority of both the two- and four-year institutions came from the North Central accrediting region (Table 1). Additionally, nearly three-fourths of the four-year institutions and all of the two-year institutions were public institutions. The four-year institutions varied in their admissions selectivity policies, though the majority (79%) had traditional or selective admissions policies. Two state systems provided data on all of their two- and four-year public institutions, representing 100% of the two-year institutions and 63% of the four-year institutions included in this sample.[10] Tracking across a state system is particularly relevant for the two-year sample, given that many students beginning at two-year institutions transfer to a four-year institution without first receiving a credential from the two-year institution (Shapiro, Dundar, Ziskin, Chiang, Chen, Torres, & Harrell, 2013).

Table 1. Institutional Characteristics by Type of Institution

Institutional Characteristic	Four-Year Institutions	Two-Year Institutions
Number of Institutions	49	36
Number of STEM Major Students	63,090	12,829
Number of States Represented	13	2
Affiliation		
Public	71%	100%
Private	29%	0%
Selectivity		
Selective/Highly Selective	24%	0%
Traditional	55%	6%
Liberal/Open	20%	94%
Accrediting Region		
North Central	78%	100%
Southern	22%	0%

Note: The typical number of STEM major students per institution was 185 students (ranged from 36 to 1,970) at the two-year institutions and 689 students (ranged from 19 to 5,547) at the four-year institutions. The selectivity of the institution's admission policies was self-reported by the institutions using five levels that classified their level according to the typical high school ranks of their accepted freshmen; the five levels included: highly selective, selective, traditional, liberal, and open. A majority of admitted students at the selective/highly selective institutions are from the top 25% of their high school class.

Supplemental analyses were conducted to examine the selectivity levels of the institutions attended by a national sample of ACT-tested students who graduated from high school in 2007, indicated that they planned to major in a STEM-related field in college, and enrolled in a four-year postsecondary institution in fall 2007. Compared to the national sample, we found there to be fewer highly selective/selective institutions included in this study's four-year sample (24% for study sample vs. 37% for national sample).[11]

[10] For one state, college outcomes were provided for all public and some private institutions in the state.

[11] The national sample included 191,854 students. Enrollment information for the national sample was based on data from the National Student Clearinghouse.

Measures

In addition to major CIP codes, institutions also provided term-by-term data on enrollment status and cumulative GPA as well as degree information, including date, type, and title.[12] Data for students' demographic characteristics, high school coursework taken, grades earned in those courses, educational plans, major plans and interests, and test scores were obtained from the ACT student record. Students provided this information at the time they registered to take the ACT. At the same time, students were also asked to complete the ACT Interest Inventory. If students took the ACT more than once, only data from the most recent ACT administration was used.

Study Outcomes

Outcomes for the study included persistence in a STEM-related field through year 4, indicators for whether a student's annual cumulative GPA was 3.0 or higher through year 4, and STEM degree completion through year 6. Outcomes were examined separately by institution type, where type was defined at time of initial enrollment. Evaluation of six-year degree completion rates for the four-year sample represents completion within 150% of normal time. The longer-term outcomes are also meaningful for the two-year sample, given that these students were tracked across in-state postsecondary institutions.

For both two- and four-year institutions, persistence in a STEM-related field was coded into three distinct categories:

- persisting in a STEM major (labeled as "persisted in STEM")
- leaving STEM by switching to a non-STEM major (labeled as "left STEM")
- not enrolled without a degree (labeled as "not enrolled")

For each time point evaluated (year 2, year 3, year 4), the three-category STEM persistence outcome was based on students' declared majors during the spring semester of the corresponding year. Students who were no longer enrolled but who had completed a bachelor's degree were categorized as persisting in STEM or switching to non-STEM according to their degree major.[13] For both two- and four-year institutions, analyses of cumulative grades at the end of year 2, year 3, and year 4 were based on the subsample of students who persisted in a STEM major to ensure that a majority of their grades were earned in STEM-related courses. For degree completion, time to a bachelor's degree in a STEM-related field was evaluated for students who initially enrolled in a four-year institution (referred to as the four-year sample in this report) and time to an associate's or bachelor's degree in a STEM-related field was evaluated for students who initially enrolled in a two-year institution (referred to as the two-year sample).[14] We were able to use the latter definition because the two-year sample came from two state systems where transfer information to an in-state four-year institution was tracked. Analyses for the persistence and degree completion outcomes were based on the entire initial two-and four-year samples of students. Cohorts of students that had fewer than six years of follow-up data available were included in the degree completion analyses by being treated as censored observations for the time periods that their degree status was unknown

[12] Cumulative GPA was provided by 45 four-year institutions and 35 two-year institutions.

[13] For example, in analyses for subsequent years, students who terminated after two years were classified as (1) not enrolled if they were no longer enrolled without a degree, (2) persisted in STEM if they completed a STEM degree prior to their departure, or (3) left STEM if they completed a non-STEM degree prior to their departure.

[14] For the two-year sample, we did not evaluate certificate attainment in this study. Information on technical certificates was only provided for one of the state systems. This decision seems appropriate given that a majority of STEM occupations require at least an associate's degree (Carnevale, Smith, & Melton, 2011).

(e.g., censored at years 5 and 6 for cohorts that were tracked for four years; see Singer and Willett [1993] for more discussion on this topic).

Academic Achievement and Preparation Measures, Student Demographics, and Educational Plans

Academic coursework measures included:

- highest mathematics course taken in high school (categorized as Calculus; Trigonometry or other advanced math beyond Algebra II; Algebra II; below Algebra II)
- whether advanced, accelerated, or honors courses in mathematics were taken in high school (Yes/No)
- highest science course taken in high school (categorized as Physics; Chemistry; Biology or below)[15]
- whether advanced, accelerated, or honors courses in science were taken in high school (Yes/No)

The achievement measures included the average ACT mathematics and science score[16] and high school GPA (HSGPA).[17] ACT scores and HSGPA were examined as continuous and categorical predictors. Categorizations for ACT scores were based on the average of the ACT College Readiness Benchmarks in mathematics and science (22 and 23, respectively; Allen, 2013) and the average of the ACT mathematics and science scores that are associated with a reasonable chance of success in typical first-year mathematics and science courses taken by STEM majors (27 and 25, respectively; Mattern et al., 2015).[18] Categorization for HSGPA was based on the four-year sample distribution.[19]

High school coursework and HSGPAs were based on students' self-reports of their coursework taken in 23 specific courses in English, mathematics, social studies, and science and the grades earned in these courses. Prior studies have shown that students report high school coursework and grades accurately relative to information provided in their transcripts (Sanchez & Buddin, 2016; Shaw & Mattern, 2009).

[15] Only 4% of the sample had taken Physics without first taking Chemistry and less than 1% had taken Chemistry without first taking Biology.

[16] ACT scores are reported on a scale of 1 to 36. The average ACT mathematics and science score was used instead of the individual subject scores because the two scores are highly correlated (0.81 for the 2015 ACT-tested high school graduating class); both subject areas were considered STEM-related. Additionally, beginning in fall 2015, ACT introduced a STEM score for the ACT test, which is the rounded average of the ACT mathematics and science test scores.

[17] Overall HSGPA had a stronger correlation with the study outcomes than the subject-specific HSGPAs and was therefore used in the analyses.

[18] The ACT College Readiness Benchmarks in mathematics and science were developed based on students' likely success in a first-year College Algebra and Biology course, respectively. Calculus was identified as the typical first mathematics course of students majoring in STEM. The median ACT mathematics test score associated with a 50% chance of earning a B or higher grade in Calculus was identified to be 27. The typical first science course taken was largely dependent upon a student's major, as evidenced by differences among the four STEM major categories. Based on performance in Chemistry, Biology, Physics, or Engineering, the median ACT science score associated with a 50% chance of earning a B or higher grade was identified to be 25. The average ACT mathematics and science score was categorized into the following three categories: 22 and below; 22.5 to 25.5; and 26 and above. See the ACT Technical Manual (2014a) for more detailed information about the ACT mathematics and science tests.

[19] HSGPA was categorized into the following three categories: below 3.30; 3.30 to 3.74; and 3.75 and above.

Student demographic characteristics and educational plans included:

- gender
- race/ethnicity (categorized as underrepresented minority students, White/Asian students, and other/multiracial students)[20]
- family income range (categorized as less than $36,000, $36,000 to $80,000, and more than $80,000)
- highest level of education expected to complete (categorized as bachelor's degree or below; beyond a bachelor's degree)[21]

Expressed and Measured Interests[22]

A student was identified as having an *expressed* interest in STEM if the student chose a major or occupation (out of the nearly 300 listed in the Student Profile Section of the ACT) in a STEM-related field. (Refer to ACT [2014b] for the list of 94 ACT majors/occupations that are classified as STEM.) Students' *measured* interests in STEM were based on their ACT Interest Inventory scores. On the ACT Interest Inventory, students indicate whether they like, dislike, or are indifferent to 72 common activities related to four basic work tasks: data, ideas, people, and things.[23] Examples of activities include: explore a science museum, make charts or graphs, conduct a meeting, teach people a new hobby. Based on student responses to these items, six interest inventory standard scores are calculated. These six scores correspond to the six interest types in Holland's theory of careers (ACT, 2009; Holland, 1997). The six ACT Interest Inventory scales (and the corresponding Holland type) are Technical (Realistic), Science and Technology (Investigative), Arts (Artistic), Social Service (Social), Business Administration and Sales (Enterprising), and Business Operations (Conventional). Internal consistency estimates of reliabilities of the ACT Interest Inventory standard scores range from 0.84 to 0.91 across the scales.

A student was classified as having a *measured* interest in STEM if one of the following conditions was met:

- Science and Technology (Investigative) was the highest ACT Interest Inventory score.
- Technical (Realistic) was the highest ACT Interest Inventory score, followed by Science and Technology (Investigative).

This definition is consistent with the one used in the annual ACT Condition of STEM Report (ACT, 2015). This definition is based on the empirically derived interest score profiles of major groups (ACT, 1995), occupational group (Holland, 1997), and expert ratings (Rounds, Smith, Hubert, Lewis, & Rivkin, 1999). General agreement is found across these sources: Science and Technology (Investigative) is the interest type found for most STEM majors (e.g., biology, mathematics, chemical engineering), whereas Technical (Realistic) and secondarily Science and Technology (Investigative) is the interest pair typically found for many types of STEM majors in engineering (e.g., mechanical engineering, petroleum engineering). Additional empirical evidence of derived Holland-type major

[20] Underrepresented minority students included African American, Hispanic, and American Indian/Alaskan Native students combined.

[21] Bachelor's degree or below included the following: a business/technical or certificate program, an associates' degree, a bachelor's degree, or other. Beyond a bachelor's degree included the following: a master's degree, a doctoral degree, or a professional level degree (e.g., MD, JD).

[22] The expressed and measured STEM interest definitions used in this study are consistent with those used in the ACT Condition of STEM Report (2014b, 2014c).

[23] Prior to fall 2007, students responded to 90 items on the ACT Interest Inventory.

profiles provided in a more recent study by Le et al. (2014) also supports this definition (see Appendix, Table A1).[24]

Students' interest in STEM was a combination of their expressed and measured interests in STEM and was coded using the following four categories:

- both expressed and measured interest
- expressed interest only (no measured interest)
- measured interest only (no expressed interest)
- no STEM interest

Valid information on a student's intended major and ACT Interest Inventory scores were required in order for students' interest to be classified into one of these four categories. Approximately 20% of the students were missing the STEM interest grouping variable.[25]

Method

Due to the nested structure of the data (i.e., students clustered within institutions), various hierarchical regression models were developed to predict success in a STEM major from the student and institutional characteristics (these characteristics are listed in Tables 2 [student demographic characteristics], 3 [academic achievement and preparation characteristics], and 4 [educational plans, STEM interests, and STEM major category] that are provided in the Results section).[26] Hierarchical models provide two general types of estimates: (1) the fixed effects, which estimate the value of the parameter at a typical institution, and (2) the variance estimates, which describe the variability of the parameter estimates across institutions. For each outcome variable, a single-predictor model for each predictor, as well as a multiple-predictor model based on all predictors jointly, were developed.

A hierarchical multinomial regression model employing a logit link was used for the three-category STEM persistence outcome. Persisting in a STEM major was the base category. For annual cumulative GPA dichotomized at 3.00, a hierarchical logistic regression model was used. In these models, intercepts were allowed to vary randomly across institutions.[27]

Hierarchical discrete-time models using the logit link under the proportional odds assumption were developed to predict STEM degree completion (Allison, 1995; Reardon, Brennan, & Buka, 2002; Singer & Willett, 1993). This approach simultaneously models all time periods while also accounting for censored observations due to the various freshman cohorts being tracked for differing lengths of time.[28] In these models, the logit of the conditional probability of degree completion in a particular term, given that no degree was earned prior to that term, was modeled as a linear function of term

[24] The Holland-type major profiles are based on the average ACT Interest Inventory scores across successful students within a major (e.g., defined as third-year students who have maintained a cumulative grade point average of 2.0 or above).

[25] The ACT Condition of STEM report (2015) reports academic achievement levels for the three STEM interest categories: both expressed and measured, expressed only, measured only. However, the definitions for the expressed-only and measured-only groups differ from those used here. For example, the expressed-only group used in the ACT Condition of STEM report (2015) also includes students with expressed interest in STEM who are missing their measured interest in STEM. Similarly, the measured-only group also includes students with measured interest in STEM who are missing information on their intended major/occupation.

[26] The GLIMMIX procedure for generalized mixed models, available in SAS 9.2, with the Laplace estimation method and generalized logit link was used to fit the models.

[27] For persistence in STEM and annual cumulative GPA dichotomized at 3.00 or higher, a random intercept and slope model did not converge for most predictors. In instances where the results did converge, the random intercept model and the random intercept and slope model provided nearly identical results. Only results from the random intercept models are reported.

[28] Using a method that accounted for censored observations allowed us to report on six-year degree completion rates based on the full sample of students that were examined in the STEM persistence analyses.

indicators and the student and institutional characteristics.[29] As discussed in Singer and Willett (1993), the discrete-time models were estimated from a data file that included multiple records per student—one for each academic term through the time of degree completion for completers and through the time of being tracked for non-completers. The term indicators were estimated based only on students who were tracked through the specific term and had not yet completed a degree in a prior term, thereby not including in the estimations those for which their degree completion status during a specific term was unknown (i.e., the censored observations).

The discrete-time analyses focused on fall and spring terms. There were very few degrees given in the summer terms; summer term degree completion was therefore combined with that for the prior spring term. Term indicators for term 6 (spring/summer term of year 3) through term 12 (spring/summer term of year 6) were included in the bachelor's degree completion models for the four-year sample.[30] For the two-year sample where completion of an associate's or bachelor's degree in STEM was examined, term indicators for term 4 through term 12 were included in the models. Parameter estimates for the term indicators and student characteristics were allowed to vary randomly across institutions.

For each variable, the odds ratio (OR) was reported as a means to compare the strength of the predictor-outcome relationships among student characteristics. For a dichotomized outcome, the OR represents the odds of experiencing the outcome (e.g., earning a cumulative GPA of 3.00 or higher) for a certain subgroup of students (e.g., female students or students taking advanced, accelerated, or honors mathematics courses), compared to the odds of experiencing the outcome for another subgroup of students (e.g., male students or students not taking advanced, accelerated, and honors mathematics courses; the latter group is often referred to as the referent group). For the multinomial STEM persistence outcome, two ORs of STEM attrition compared to the base category (persisting in STEM) are reported: the OR of not being enrolled vs. persisting in STEM, and the OR of leaving STEM (switching to non-STEM) vs. persisting in STEM.[31]

In comparison to members in the referent group, an OR greater than 1.0 indicates that students in the subgroup of interest are generally more likely to experience the outcome of interest, whereas an OR less than 1.0 indicates that they are less likely to do so. An OR estimated from a single-predictor model is labeled as an *unadjusted OR.* An OR estimated from a multiple-predictor model is labeled as an *adjusted OR*, because other student characteristics were adjusted for in the model. The change from the unadjusted to the adjusted OR for a predictor is one indication of the degree to which the other variables influence the strength of the predictor-outcome relationship. The 95% confidence interval for the OR provides an indication of whether the relationship is statistically significant at the 0.05 level (that being when the interval does not include the null value of 1.0). For

[29] The conditional probability of degree completion in a particular term (say term j), given that no degree was earned prior to that term is often referred to as the discrete-time hazard function for term j (denoted as h(j); Singer & Willett, 1993). These conditional probabilities of success are calculated per academic term using the parameter estimates obtained from the discrete-time models in the same manner that probabilities of success are calculated from logistic regression parameter estimates. The probability of completing a degree in more than j terms is equal to the product of the conditional probabilities of completing a degree in more than j terms given the no degree was earned prior to term j (that is, the product of $(1 - h(i))$ from $i = 1$ to j). The probability of completing a degree within j or fewer terms is equal to one minus the probability of completing a degree in more than j terms.

[30] Term 4 is for the end of year 2, term 6 is for the end of year 3, term 8 is for the end of year 4, term 10 is for the end of year 5, and term 12 is for the end of year 6.

[31] For a multinomial outcome, the odds of experiencing a specific outcome (such as, no longer enrolled at initial institution) is the ratio of the probability of experiencing the outcome (no longer enrolled at initial institution) to the probability of experiencing the base outcome (persisted in STEM). For a dichotomized outcome, the odds is the ratio of the probability of experiencing the outcome (e.g., earned a cumulative GPA of 3.00 or higher) to the probability of not experiencing the outcome (earned a cumulative GPA below 3.00).

each outcome, adjustment was made for only those student characteristics that were found to be statistically significant at the 0.05 level in the multivariate model. Adjusted results were, however, reported for all student characteristics.

In addition to ORs, STEM success and attrition rates by student characteristics were reported to help provide context for the practical significance of the findings, especially in light of the relatively large sample size. In multivariate analyses, STEM success and attrition rates by student characteristics were estimated using the fixed effect parameter estimates from the hierarchical models and holding all other student-level variables in the model constant at the sample (grand) means. Additionally, to account for the overrepresentation of less-selective institutions in the four-year sample, we reported ORs and STEM success rates that adjusted for institution selectivity (labeled *institution selectivity adjusted* results) instead of reporting *unadjusted* results. Rates for the four-year sample were estimated under the assumption that 37% of the institutions attended by STEM majors are selective institutions (an estimate obtained from a national sample of ACT-tested students intending to major in STEM).[32]

Examination of the second objective of this study involved evaluating all possible interaction terms with declared STEM major group. For student characteristics that significantly interacted with STEM major group, adjusted ORs were estimated within each STEM major category.

Some students did not respond to high school coursework and grade items, as well as to the family income range and educational plans items, when they completed the ACT registration materials. Multiple imputation was used to estimate missing values for these student characteristics; missing rates ranged from 11% (for educational plans) to 28% (for advanced high school science coursework).[33] Five data sets were imputed. The multiple-predictor models were developed for all five imputed data sets; no differences of practical significance in the estimated ORs were found across the data sets. The results reported are therefore based only on the initial imputed data set. Missing values were not imputed for gender, intended major, and ACT Interest Inventory scores. As a result, the multiple-predictor models for STEM persistence at year 4 and degree completion were based on 49,405 students for the four-year sample and 10,455 students for the two-year sample due to missing values in gender and students' expressed and measured interest in STEM.

[32] Institutional characteristics were included as level-2 predictors.

[33] Missing values were imputed using the MI procedure in SAS 9.2. The MI procedure replaces missing values of variables with plausible values based on non-missing data. Missing rates for the other imputed variables included: 23% for family income, 16% for HSGPA, 17% for mathematics coursework taken, 15% for science coursework taken, and 27% for advanced high school mathematics coursework taken.

Results

Description of Study Samples

Table 2 contains descriptive statistics on student demographics for the study samples. Female students made up 50% of the four-year sample and 55% of the two-year sample. For both samples, approximately one-fourth of the students were underrepresented minority students.[34] The two-year sample was comprised of a higher percentage of lower-income students (40% vs. 26%).

Table 2. Description of Student Demographics by Study Samples

	Four-Year Sample (N = 63,090)		Two-Year Sample (N = 12,829)	
Student Characteristic	*n*	Percent	*n*	Percent
Gender				
Male	30,375	50	5,673	45
Female	30,510	50	6,917	55
Race/Ethnicity				
Minority	13,744	22	3,241	25
Other/Multiracial	5,737	9	1,001	8
White/Asian	43,609	69	8,587	67
Annual Family Income				
< $36,000	16,388	26	5,121	40
$36,000 to $80,000	26,578	42	5,756	45
> $80,000	20,124	32	1,952	15

Note: Gender percentages based on respondents only (3% missing for the four-year sample and 2% missing for the two-year sample).

[34] A similar finding was observed for the sample of 2007 ACT-tested high school graduates who planned to major in STEM and enrolled in college in fall 2007 grouped by institution type (percentage of female students: 53% and 57%; percentage of racial/ethnic minority students: 19% and 23% for the four- and two-year 2007 samples).

Table 3 provides descriptive statistics on students' academic preparation and achievement measures. Compared to the two-year sample, STEM majors in the four-year sample were over three times more likely to take a Calculus course in high school, and about two times more likely to take a Physics course, as well as to take an advanced, accelerated, or honors course in mathematics or science. STEM majors in the four-year sample tended to have higher HSGPAs and average ACT mathematics and science scores than those in the two-year sample.[35] Nearly one-half of the STEM majors in the four-year sample were enrolled in a more-selective institution.[36]

Table 3. Description of Academic Preparation and Achievement Measures by Study Samples

	Four-Year Sample (N = 63,090)		Two-Year Sample (N = 12,829)	
Student Characteristic	*n*	Percent	*n*	Percent
Highest Mathematics Course				
Calculus	16,679	26	941	7
Trig/Other Advanced Mathematics	29,802	47	5,108	40
Algebra II	15,169	24	5,833	45
Below Algebra II	1,440	2	947	7
Highest Science Course				
Physics	27,411	43	2,564	20
Chemistry	28,447	45	5,974	47
Biology or Below	7,232	11	4,291	33
Advanced HS Mathematics Coursework				
No	19,427	31	8,331	65
Yes	43,663	69	4,498	35
Advanced HS Science Coursework				
No	21,765	34	8,387	65
Yes	41,325	66	4,442	35
Average ACT Mathematics and Science Score				
≤ 22	25,897	41	10,670	83
22.5 to 25.5	17,498	28	1,656	13
≥ 26	19,695	31	503	4
HSGPA				
< 3.30	16,843	27	7,288	57
3.30 to 3.74	18,700	30	3,353	26
≥ 3.75	27,547	44	2,188	17
Selectivity of Institution Attended				
Less-Selective	32,654	52	12,829	100
Selective	30,436	48	0	0

Note: Less-selective institutions included those with more traditional, liberal, or open admissions policies.
Trig = trigonometry.

[35] This finding was also observed for the sample of 2007 ACT-tested high school graduates who planned to major in STEM and enrolled in college in fall 2007. Moreover, the average ACT mathematics and science score and HSGPA distributions for the 2007 sample disaggregated by initial institution type were similar to those for the study samples.

[36] This percentage is consistent with that for two other samples: the sample of 2007 ACT-tested high school graduates who planned to major in STEM and enrolled in a four-year postsecondary institution in fall 2007 (50%) and another nationally-represented sample of STEM majors who began postsecondary education in 1995–1996 (52%; Chen, 2009).

Table 4 provides descriptive statistics on students' educational plans, STEM interests, and STEM major category. Many students in both samples had educational plans beyond a bachelor's degree (66% and 41% for the four- and two-year samples). STEM interest information was not provided for approximately 20% of students.[37] Of those providing interest information, a majority of STEM majors had expressed and/or measured interest in STEM; 20% of four-year STEM majors and 28% of two-year STEM majors had neither expressed nor measured interest. In terms of the distribution of declared STEM majors by STEM category, the most prevalent STEM major category was Science for the four-year sample and Medical & Health for the two-year sample.

Table 4. Description of Educational Plans, STEM Interests, and STEM Major Category by Study Samples

	Four-Year Sample (N = 63,090)		Two-Year Sample (N = 12,829)	
Student Characteristic	*n*	Percent	*n*	Percent
Educational Plans				
Bachelor's or Below	21,243	34	7,512	59
Beyond Bachelor's	41,847	66	5,317	41
STEM Interest				
Expressed and Measured	17,545	35	2,956	28
Expressed Only	18,034	36	3,694	35
Measured Only	4,193	8	953	9
No Interest	10,193	20	2,941	28
STEM Major Category				
Engineering & Technology	16,387	26	3,224	25
Medical & Health	13,345	21	5,661	44
Computer Science & Mathematics	8,214	13	1,684	13
Science	25,144	40	2,260	18

Note: STEM interest percentages based on respondents only (21% missing for the four-year sample and 18% missing for the two-year sample).

[37] Student and institutional characteristics, as well as STEM success rates were similar between the entire study samples and the restricted samples that included students with STEM interest information only.

Table 5 provides a summary of the modeled STEM success rates by year for both samples, after accounting for variability across institutions and institution selectivity (the latter for the four-year sample only due to the overrepresentation of less-selective institutions in the study sample).[38]

Table 5. Modeled STEM Success Rates by Year for Study Samples

Outcome	Four-Year Sample	Two-Year Sample
Persisted in STEM		
Year 2	63	41
Year 3	50	33
Year 4	45	29
Left STEM; Switched to Non-STEM		
Year 2	15	17
Year 3	19	19
Year 4	19	18
Not Enrolled		
Year 2	22	42
Year 3	31	48
Year 4	35	53
Earned Cumulative GPA of 3.00 or Higher[1]		
Year 2	54	42
Year 3	60	47
Year 4	63	52
STEM Degree Completion		
Year 4	16	13
Year 5	27	17
Year 6	30	19

Note: STEM success rates for the four-year sample adjusted for institution selectivity.

[1] *The* number of persisting STEM majors included in the cumulative GPA analyses decreased from 37,343 to 27,497 between years 2 and 4 for the four-year sample and from 7,954 to 3,608 for the two-year sample.

For STEM majors at both two- and four-year samples, the typical STEM persistence rates decreased between years 2 and 4, while the percentage of students no longer enrolled increased during this time period. Additionally, the non-STEM switch rate increased slightly for the four-year sample, but the rate was relatively constant over time for the two-year sample. The percentage of STEM majors earning a cumulative GPA of 3.00 or higher increased over time. This latter result is likely due to the STEM attrition that occurred. The typical STEM bachelor's degree completion rate for the four-year sample increased from 16% by year 4 to 30% by year 6.[39] Rates for completing an associate's or bachelor's degree for the two-year sample were lower, with only 19% of STEM majors starting

[38] STEM success rates for the four-year sample were adjusted for institution selectivity evaluated at 37% (the percentage observed in the 2007 national sample of ACT-tested high school graduates who planned to major in STEM and enrolled in a four-year institution in fall 2007). This adjustment increased the typical year 4 STEM persistence rate from 42% to 45% and the six-year STEM bachelor's degree completion rate from 28% to 30% and decreased the year 4 not-enrolled rate from 38% to 35%. The percentage of students earning a cumulative GPA of 3.00 or higher remained the same.

[39] The observed STEM bachelor's degree completion rates for the four-year sample were 22%, 36%, and 39% at years 4, 5, and 6, respectively. In comparison, the corresponding observed bachelor's degree completion rates in any major were 29%, 50%, and 55%, respectively.

at two-year institutions doing so by year 6.[40] Of students from the two-year sample completing a STEM degree, 63% completed an associate's degree, 20% completed a bachelor's degree, and 17% completed both an associate's and bachelor's degree. In comparison, a study by Chen (2009) reported that 37% of STEM majors nationally from the 1995–96 freshman cohort completed a STEM degree within six years.

STEM Success Rates over Time by Student Characteristics

STEM success and attrition rates by individual student characteristics were evaluated over time. It was generally the case that differences in STEM success rates among students' academic achievement and preparation characteristics were larger at year 4 than at year 2 for STEM persistence rates and at year 6 than at year 4 for STEM degree completion rates. For example, as illustrated in Figure 1, differences in STEM persistence rates increased from 21 percentage points at year 2 (76% vs. 55%) to 30 percentage points at year 4 (64% vs. 34%) between students with higher (26 or higher) and those with lower (22 or lower) average ACT mathematics and science scores. This finding was primarily due to there being a larger difference in the percentage of students no longer enrolled at year 4 than at year 2; the difference in the percentage of students leaving STEM and switching into a non-STEM major was more similar during this time frame (8 and 9 percentage points at years 2 and 4, respectively).

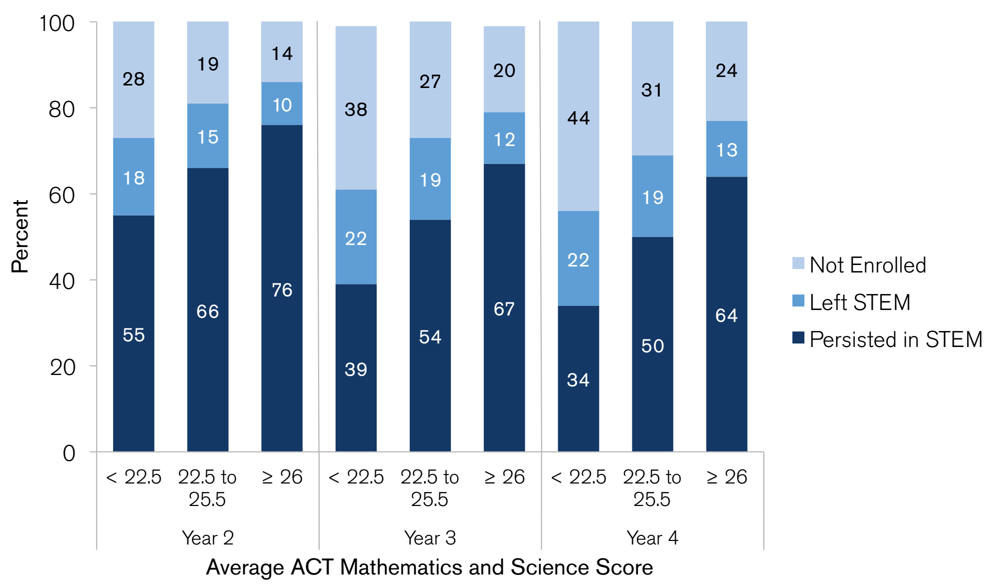

Figure 1. Modeled STEM persistence rates by average ACT mathematics and science score for the four-year sample, adjusting for institution selectivity

Additionally, based on a model that included ACT score and institution selectivity, it was estimated that 53% of STEM majors who began at a four-year institution with an average ACT mathematics and science score of 26 or higher completed a STEM bachelor's degree within six years. In comparison, only 19% of STEM majors with an average ACT mathematics and science score

[40] The observed STEM associate's or bachelor's degree completion rates for the two-year sample were 15%, 19%, and 22% at years 4, 5, and 6, respectively. In comparison, the corresponding observed associate's or bachelor's degree completion rates in any major were 24%, 31%, and 36%.

of 22 or below did so. These results illustrate that many STEM majors who are better prepared academically do not complete a STEM degree (47% estimated in this study), while there are some less academically prepared students who are able to do so (19% estimated in this study).

Because most of the student characteristics remained statistically significant in the multivariate models, we limit our discussion on the findings from the single-predictor models, and instead we discuss in detail in the next section the findings from the multivariate results. For brevity, modeled STEM success rates, attrition rates, and ORs by student characteristics from the single-predictor models are not presented here but can be made available upon request.

Multivariate Results by Student Characteristics

In the multivariate analyses, we focus on the following outcomes: STEM persistence at year 4, STEM persisters' chances of earning a cumulative GPA of 3.00 or higher at year 4, and STEM degree completion through the end of year 6. For most of the variables, because many of the variables were highly related to one another, the adjusted ORs from the multivariate models were smaller than the ORs from the bivariate analyses. After students' academic preparation and achievement characteristics were taken into account, "students' educational plans" was no longer significantly related to STEM success rates and therefore not included in the presentation of the multivariate results. Variability estimates for the random intercepts and term indicators from the null and multivariate models are provided in Appendix B, Tables B1 to B3. The intraclass correlation coefficients (ICCs) are provided in the notes of these tables. The ICCs suggested that the proportion of the total variance that is between institutions varied across the various binary outcomes that comprise the study outcomes from 0.07 to 0.26 for the four-year sample and from 0.03 to 0.29 for the two-year sample.

STEM Persistence at Year 4

The modeled STEM persistence and attrition rates at year 4 and adjusted ORs for the not-enrolled vs. persisted comparison and the left-STEM vs. persisted comparison based on a multivariate multinomial logit model are provided in Table 6 for the four-year sample and Table 7 for the two-year sample. Corresponding results by student demographic characteristics are provided in Appendix C, Table C1. For the four-year sample, all of the academic preparation, academic achievement, STEM interest, and student demographic variables were significantly related to STEM persistence at year 4. For the two-year sample, the one exception to this finding was that taking advanced high school coursework in science was not significantly related to STEM persistence at year 4. Based on McFadden's R^2 analog (McFadden, 1974), the percentage of variance explained by the multivariate model was around 6% for each sample.

For both samples, students who took higher-level mathematics and science coursework in high school were slightly more likely to persist in STEM than those who did not. This result was especially notable when persistence rates were examined by the highest mathematics course taken in high school. Specifically, students who took Calculus had higher STEM persistence rates than those who took Algebra II as their highest mathematics course in high school (52% vs. 45% for the four-year sample and 35% vs. 29% for the two-year sample). The higher persistence rates seen among students who took higher-level high school mathematics and science coursework were largely attributable to these students being less likely to drop out. From a practical significance perspective, the high school coursework taken in mathematics and science had little to no effect on STEM attrition rates due to students switching into non-STEM majors.

Table 6. Multivariate Results for STEM Persistence at Year 4 for the Four-Year Sample

Student Characteristics	Modeled Rates: Not Enrolled	Modeled Rates: Left STEM	Modeled Rates: Persisted in STEM	Not Enrolled vs. Persisted in STEM: OR	Not Enrolled vs. Persisted in STEM: 95% CI		Left STEM vs. Persisted in STEM: OR	Left STEM vs. Persisted in STEM: 95% CI	
Highest Mathematics Course									
Calculus	30	18	52	0.73	0.68	0.79	0.81	0.75	0.88
Trig/Other Advanced Mathematics	32	20	48	0.85	0.80	0.90	0.97	0.91	1.04
Algebra II	36	19	45						
Below Algebra II	38	18	44	1.08	0.91	1.28	0.96	0.79	1.16
Highest Science Course									
Physics	33	19	49	0.88	0.80	0.96	0.92	0.84	1.01
Chemistry	32	20	48	0.86	0.79	0.94	0.99	0.91	1.08
Biology or Below	35	19	46						
Advanced HS Mathematics Coursework									
No	34	20	46						
Yes	32	19	49	0.91	0.86	0.97	0.91	0.85	0.98
Advanced HS Science Coursework									
No	35	19	46						
Yes	31	20	49	0.83	0.78	0.87	0.97	0.91	1.03
Average ACT Mathematics and Science Score									
≤ 22	37	23	40						
22.5 to 25.5	31	20	49	0.71	0.67	0.75	0.73	0.68	0.78
≥ 26	28	14	58	0.53	0.49	0.57	0.45	0.42	0.48
Overall HSGPA									
< 3.30	47	19	34						
3.30 to 3.74	35	20	45	0.56	0.53	0.60	0.81	0.76	0.87
≥ 3.75	24	18	58	0.30	0.28	0.32	0.58	0.54	0.62
STEM Interest									
Expressed and Measured	33	16	51	0.84	0.79	0.90	0.56	0.52	0.60
Expressed Only	33	20	48	0.90	0.85	0.96	0.73	0.68	0.78
Measured Only	32	20	48	0.89	0.81	0.97	0.76	0.69	0.84
No Interest	33	24	43						
Selectivity of Institution Attended									
Less-Selective	37	20	44						
Selective	29	19	53	0.65	0.51	0.82	0.78	0.42	1.44

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in the table, as well as for gender, race/ethnicity, and family income range (see Appendix C, Table C1 for student demographic results). OR = odds ratio; CI = confidence interval.

Table 7. Multivariate Results for STEM Persistence at Year 4 for the Two-Year Sample

Student Characteristics	Modeled Rates: Not Enrolled	Modeled Rates: Left STEM	Modeled Rates: Persisted in STEM	Not Enrolled vs. Persisted in STEM: OR	95% CI		Left STEM vs. Persisted in STEM: OR	95% CI	
Highest Mathematics Course									
Calculus	46	19	35	0.68	0.56	0.83	0.87	0.68	1.10
Trig/Other Advanced Mathematics	49	19	32	0.80	0.72	0.89	0.92	0.81	1.05
Algebra II	52	19	29						
Below Algebra II	61	15	25	1.27	1.03	1.55	0.93	0.71	1.21
Highest Science Course									
Physics	54	17	30	0.95	0.82	1.09	0.88	0.73	1.05
Chemistry	50	19	31	0.85	0.76	0.95	0.96	0.83	1.10
Biology or Below	54	18	28						
Advanced HS Mathematics Coursework									
No	53	18	29						
Yes	50	19	31	0.86	0.77	0.96	0.96	0.84	1.09
Advanced HS Science Coursework									
No	52	18	29						
Yes	51	19	30	0.95	0.85	1.07	1.00	0.87	1.15
Average ACT Mathematics and Science Score									
≤ 22	53	19	28						
22.5 to 25.5	49	16	34	0.78	0.67	0.90	0.70	0.59	0.84
≥ 26	48	12	40	0.65	0.51	0.83	0.45	0.32	0.61
Overall HSGPA									
< 3.30	60	16	24						
3.30 to 3.74	47	20	33	0.57	0.51	0.63	0.90	0.78	1.03
≥ 3.75	33	22	45	0.30	0.26	0.34	0.75	0.64	0.88
STEM Interest									
Expressed and Measured	50	16	35	0.69	0.61	0.79	0.54	0.47	0.64
Expressed Only	53	17	29	0.89	0.79	1.01	0.72	0.62	0.83
Measured Only	50	20	30	0.81	0.68	0.97	0.78	0.63	0.97
No Interest	53	21	26						

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in the table (except for advanced high school coursework in science), as well as for gender, race/ethnicity, and family income range (see Appendix C, Table C1 for student demographic results).
OR = odds ratio; CI = confidence interval.

Students with higher academic achievement levels in mathematics and science were substantially more likely than those with lower levels to persist in STEM. They were also less likely to leave STEM either due to no longer being enrolled in college or switching into a non-STEM major by the end of year 4. This finding was seen for STEM majors at both two- and four-year institutions. For the four-year sample, STEM persistence rates for students with average ACT mathematics and science scores of 26 or higher were 18 percentage points higher than those with average scores of 22 or below (58% vs. 40%). For the corresponding comparison in the two-year sample, there was a 12-percentage-point difference (40% vs. 28%). This is further illustrated in Figure 2, where modeled STEM persistence and attrition rates are shown by average ACT mathematics and science score as a continuous measure for the four-year sample.

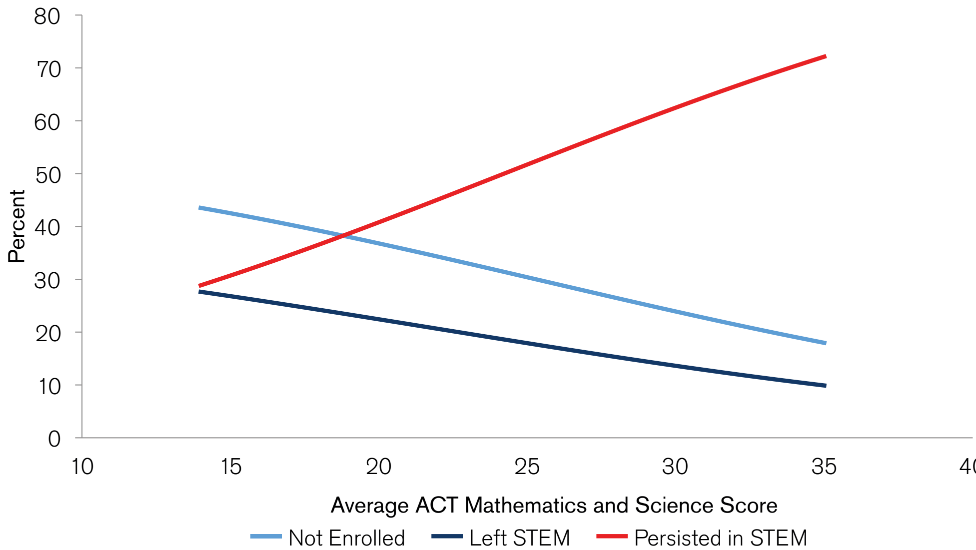

Figure 2. Modeled STEM persistence rates by average ACT mathematics and science score for four-year sample, holding all other variables constant at sample means

Additionally, compared to the less-selective four-year institutions, STEM persistence rates were higher among the more-selective institutions (53% vs. 44%). This result was primarily due to students at the less-selective institutions being more likely to no longer be enrolled (29% for selective vs. 37% for less-selective; adjusted OR = 0.65, 95% CI = (0.51, 0.82)). The STEM attrition rates due to leaving STEM by switching into a non-STEM major were comparable between the more- and less-selective institutions (19% vs. 20%; adjusted OR = 0.78, 95% CI = (0.42, 1.44)).

For both samples, students with higher HSGPAs were also substantially more likely than those with lower HSGPAs to persist in STEM (by more than 20 percentage points when comparing students with HSGPAs of 3.75 or higher and those with HSGPAs below 3.30). The adjusted odds of not being enrolled compared to persisting for students with HSGPAs of 3.75 or higher was 0.3 times that for students with HSGPAs below 3.30, whereas the adjusted odds of leaving STEM compared to persisting in STEM for the higher HSGPA group was only 0.6 to 0.8 times that for the referent group. Although both adjusted ORs were significantly different from the null value of 1.0, examination of the modeled rates suggest that from a practical perspective, the greater chances of STEM persistence were primarily due to a larger percentage of students with lower HSGPAs no longer being enrolled in college, especially for the four-year sample.

Students' interest in STEM also helped explain who was more likely to persist in STEM at both two- and four-year institutions. Specifically, compared to those with no STEM interest, modeled STEM persistence rates were 8 to 9 percentage points higher for students with both expressed and measured interests in STEM and 3 to 5 percentage points higher for students with either expressed or measured interest in STEM. The higher STEM persistence rate for students with STEM interests was more noticeably due to a smaller percentage of these students leaving STEM and switching into a non-STEM major.

When examining student demographic differences in STEM persistence rates, we found that female students were slightly more likely than male students to leave STEM by switching into a non-STEM major, while males students were slightly more likely to no longer be enrolled (Appendix C, Table C1). As a result, STEM persistence rates were fairly comparable between female and male students. For the four-year sample, both STEM attrition and persistence rates for underrepresented minority students were similar to those for White/Asian students. For the two-year sample, underrepresented minority students were more likely than White/Asian students to no longer be enrolled, but they were also slightly less likely to leave STEM by switching into a non-STEM major (Table C1). The modeled STEM persistence rate for underrepresented minority students was only 3 percentage points lower than that for White/Asian students. Lower-income students were less likely than higher-income students to persist in STEM (by 9 and 6 percentage points for the four- and two-year samples, respectively). This result was largely due to lower-income students being more likely than higher-income students to no longer be enrolled in college (by 11 and 12 percentage points). It is important to keep in mind that these demographic comparisons were taken from the multiple-predictor model results. The reported racial/ethnic and income group differences in STEM persistence rates were reduced when students' academic preparation, achievement, and interests were taken into account as compared to the results from the bivariate analyses (larger reductions were seen among the racial/ethnic groups than among the family income groups).[41]

Cumulative GPA

Table 8 provides the modeled chances of STEM persisters earning a cumulative GPA of 3.0 or higher at year 4 and the corresponding adjusted ORs. Based on McFadden's R^2 analog (McFadden, 1974), the percentage of variance explained by the multivariate model was around 14% for the four-year sample and around 10% for the two-year sample.

Table 8. Multivariate Results for STEM Persisters' Chances of Earning a 3.00 or Higher Cumulative GPA by Study Sample

	Four-Year Sample					Two-Year Sample				
Student Characteristic	N	Rate	OR	95% CI		N	Rate	OR	95% CI	
Highest Mathematics Course										
Calculus	10,569	62	1.12	1.02	1.24	415	50	1.17	0.88	1.55
Trig/Other Advanced Mathematics	14,637	62	1.10	1.01	1.20	1,727	50	1.17	0.99	1.38
Algebra II	5,772	60				1,524	46			
Below Algebra II	444	58	0.95	0.71	1.27	199	44	0.91	0.65	1.27
Highest Science Course										
Physics	15,896	61	0.91	0.79	1.05	889	48	1.05	0.85	1.30
Chemistry	13,057	62	0.95	0.83	1.09	1,904	49	1.10	0.93	1.32
Biology or Below	2,469	63				1,072	46			
Advanced HS Mathematics Coursework										
No	6,160	59				2,087	46			
Yes	21,337	62	1.15	1.06	1.25	1,521	51	1.22	1.04	1.42

[41] For example, for the four-year sample, racial/ethnic and family income group differences in STEM persistence rates were 11 percentage points between underrepresented minority students and White/Asian students and 14 percentage points between lower- and higher-income students, based on the institution selectivity adjusted analyses. In comparison, these group differences were 1 and 9 percentage points, respectively, based on multivariate analyses.

Table 8. (continued)

Student Characteristic	Four-Year Sample					Two-Year Sample				
	N	Rate	OR	95% CI		N	Rate	OR	95% CI	
Advanced HS Science Coursework										
No	7,450	61				2,134	48			
Yes	20,047	62	1.03	0.95	1.12	1,474	47	0.94	0.79	1.12
Average ACT Mathematics and Science Score										
≤ 22	7,933	49				2,699	46			
22.5 to 25.5	8,188	63	1.79	1.64	1.95	674	57	1.61	1.32	1.97
≥ 26	11,376	75	3.21	2.91	3.55	235	62	1.97	1.40	2.76
Overall HSGPA										
< 3.30	4,536	38				1,578	36			
3.30 to 3.74	7,756	56	2.10	1.91	2.31	1,099	54	2.10	1.77	2.48
≥ 3.75	15,205	77	5.35	4.86	5.89	931	75	5.41	4.41	6.62
STEM Interest										
Expressed and Measured	8,460	61	0.85	0.77	0.93	996	46	0.97	0.78	1.21
Expressed Only	7,718	60	0.81	0.74	0.90	1,024	48	1.06	0.86	1.32
Measured Only	1,708	63	0.92	0.80	1.06	274	51	1.18	0.87	1.61
No Interest	3,560	65				690	47			
Selectivity of Institution Attended										
Less-Selective	13,125	65								
Selective	18,297	55	0.64	0.51	0.81					

Note: Italics indicate referent group. For the four-year sample, adjustment was made for all student characteristics included in the table (except for highest science course and advanced high school coursework in science), as well as for gender, race/ethnicity, and family income range (see Appendix C, Table C2 for student demographic results). For the two-year sample, adjustment was made for race/ethnicity, advanced high school coursework in mathematics, average ACT mathematics and science score, and HSGPA. OR = odds ratio; CI = confidence interval.

For both samples, substantially higher chances of earning a cumulative GPA of 3.00 or higher at year 4 were seen for STEM persisters who had average ACT mathematics and science scores of 26 or higher (75% vs. 49% compared to those with scores of 22 or below for the four-year sample and 62% vs. 46% for the two-year sample) and earned HSGPAs of 3.75 or higher (75% to 77% vs. 36% to 38% compared to those with HSGPAs below 3.30; adjusted OR = 5.4 in both samples). Though to a lesser extent, taking higher-level and/or advanced high school coursework in mathematics (not in science) was also associated with a higher likelihood of earning a cumulative GPA of 3.00 or higher. For this latter result, the advanced high school mathematics coursework indicator was the only high school coursework variable that was statistically significant for the two-year sample.

Compared to four-year less-selective institutions, the more-selective institutions had a smaller percentage of STEM persisters who earned a cumulative GPA of 3.00 or higher at year 4 (55% vs. 65%; adjusted OR = 0.64). Another significant predictor for the four-year sample was students' interest in STEM. Specifically, students with both expressed and measured interest in STEM, as well as those with expressed-only interest, were slightly less likely than those with no interest in STEM to earn a cumulative GPA of 3.00 or higher at year 4 (61% and 60% vs. 65%, respectively). This latter result, which seems counterintuitive, is most likely due to STEM attrition at year 4 being more prevalent for the no-STEM-interest group.

In terms of student demographic differences in cumulative GPA rates among STEM persisters, we found that, in both samples, underrepresented minority students were less likely than White/Asian students to earn a cumulative GPA of 3.00 or higher at year 4 (Appendix C, Table C2; by 9 to 12 percentage points). Differences in cumulative GPA rates were also seen among gender and family income groups for the four-year sample. Specifically, among STEM persisters, female students and higher-income students had a greater likelihood of earning a cumulative GPA of 3.00 or higher at year 4 than male students and lower-income students (by 14 and 9 percentage points, respectively).

Degree Completion

In the multivariate hierarchical discrete-time models, not only did the term indicators significantly vary across institutions, but this was also the case for the effects of some of the student characteristics. For the four-year sample, academic terms 6 through 12 were included in the model as random effects. For the two-year sample, academic terms 4 through 12 were included in the model, but only the even-numbered terms (the ones at the end of each year from year 2 to year 6) were included as random effects.[42] The variance estimates for the term indicators were generally greater for earlier terms than for the later terms (Appendix B, Table B3). The variation in the term indicators across institutions corresponded to wide variability in degree completion rates over time across institutions.

For the four-year sample, gender, average ACT mathematics and science score, and HSGPA were included as random effects (Appendix B, Table B3). For the two-year sample, gender was the only predictor included as a random effect. By including these predictors as random effects, we are accounting for the possibility that their effects on STEM degree completion might be more important at some institutions than at others. The estimated fixed effects for these predictors are estimates of the average effects across all institutions. The modeled STEM degree completions rates and adjusted ORs by student and institutional characteristics are provided in Table 9 for the four-year sample and Table 10 for the two-year sample. In general, the term indicators had greater variability across institutions than the student predictors did (Appendix B, Table B3). Moreover, there tended to be a reduction in the random slope variance estimates associated with the term indicators when student predictors were included in the model as compared to the corresponding estimates from the null model that did not include student-level predictors.

We highlight only a few of the STEM degree completion findings because results for the relationships between student characteristics and STEM degree completion were in general agreement with those previously discussed in detail for STEM persistence at year 4. Specifically, the findings suggest that better academic preparation in mathematics and science was positively related to STEM degree completion. For STEM majors with an average ACT mathematics and science score of 26 or above, the typical STEM bachelor's degree completion rate for the four-year sample increased from 23% at year 4 to 43% at year 6.

[42] The variance estimates of the odd-numbered terms were not significantly different from zero.

Table 9. Multivariate Results for STEM Bachelor's Degree Completion for Four-Year Sample

Student Characteristics	Modeled Rates Year 4	Year 5	Year 6	OR	95% CI	
Highest Mathematics Course						
Calculus	18	30	35	1.24	1.17	1.32
Trig/Other Advanced Mathematics	16	27	31	1.09	1.03	1.15
Algebra II	15	26	29			
Below Algebra II	14	24	27	0.92	0.77	1.11
Highest Science Course						
Physics	16	28	32	1.13	1.03	1.15
Chemistry	16	28	32	1.12	1.03	1.21
Biology or Below	15	25	29			
Advanced HS Mathematics Coursework						
No	15	26	30			
Yes	17	28	32	1.12	1.06	1.18
Advanced HS Science Coursework						
No	15	26	29			
Yes	17	29	33	1.15	1.10	1.21
Average ACT Mathematics and Science Score						
≤ 22	12	20	23			
22.5 to 25.5	17	29	33	1.56	1.45	1.68
≥ 26	23	38	43	2.23	2.03	2.44
Overall HSGPA						
< 3.30	9	15	18			
3.30 to 3.74	15	25	29	1.75	1.61	1.90
≥ 3.75	24	40	45	3.21	2.90	3.56
STEM Interest						
Expressed and Measured	18	30	34	1.26	1.19	1.32
Expressed Only	16	27	31	1.13	1.07	1.19
Measured Only	16	28	32	1.16	1.08	1.25
No Interest	14	25	28			
Selectivity of Institution Attended						
Less-Selective	15	26	29			
Selective	18	31	35	1.25	1.05	1.50

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in the table, as well as for gender, race/ethnicity, and family income range (see Appendix C, Table C3 for student demographic results). OR = odds ratio; CI = confidence interval.

Table 10. Multivariate Results for STEM Associate's or Bachelor's Degree Completion for Two-Year Sample

Student Characteristics	Modeled Rates Year 4	Year 5	Year 6	OR	95% CI	
Highest Mathematics Course						
Calculus	13	17	20	1.31	1.10	1.56
Trig/Other Advanced Mathematics	13	16	19	1.24	1.11	1.38
Algebra II	10	14	15			
Below Algebra II	9	12	14	0.90	0.71	1.13
Highest Science Course						
Physics	11	15	17	1.08	0.94	1.25
Chemistry	12	16	18	1.16	1.03	1.30
Biology or Below	11	14	16			
Advanced HS Mathematics Coursework						
No	11	14	16			
Yes	12	16	18	1.16	1.03	1.30
Advanced HS Science Coursework						
No	11	14	16			
Yes	12	16	18	1.13	0.95	1.35
Average ACT Mathematics and Science Score						
≤ 22	11	14	16			
22.5 to 25.5	14	19	21	1.37	1.21	1.55
≥ 26	16	21	23	1.57	1.27	1.86
Overall HSGPA						
< 3.30	8	11	12			
3.30 to 3.74	15	19	22	1.93	1.72	2.16
≥ 3.75	22	28	31	2.98	2.63	3.37
STEM Interest						
Expressed and Measured	13	17	19	1.31	1.15	1.48
Expressed Only	11	14	16	1.09	0.96	1.23
Measured Only	11	15	17	1.13	0.95	1.35
No Interest	10	13	15			

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in the table (except for advanced high school coursework in science), as well as for gender, race/ethnicity, and family income range (see Appendix C, Table C3 for student demographic results). OR = odds ratio; CI = confidence interval.

In comparison, only 23% of STEM majors with an average score of 22 or below completed a STEM degree by the end of year 6. Additionally, a 27-percentage-point difference in the six-year STEM bachelor's degree rate was found between students with a HSGPA of 3.75 or higher and those with a HSGPA below 3.30 (45% vs. 18%). For the two-year sample, differences in the percentages of students completing an associate's or bachelor's degree in STEM were considerably smaller between the highest and lowest ACT score groups, compared to those between the highest and lowest HSGPA groups (7 percentage points vs. 19 percentage points at year 6; adjusted OR = 1.6 vs. 3.0).

STEM interest was also found to be significantly related to STEM degree completion. For example, students with both expressed and measured interest in STEM had higher STEM degree completion rates than those with no STEM interest (34% vs. 28% at year 6 for the four-year sample and 19% vs. 15% for the two-year sample). STEM degree completion rates were only slightly higher for students with one type of interest in STEM as compared to those with no STEM interest; this result was statistically significant for the four-year sample only.

In contrast to the STEM persistence results by gender and race/ethnicity for the four-year sample, female and Asian/White students were significantly more likely than male and underrepresented minority students to complete a bachelor's degree in STEM. These differences, however, were small (33% vs. 30% and 32% vs. 29% at year 6, respectively; Appendix C, Table C3). The corresponding comparisons for the two-year sample, as well as the comparisons by family income group for both samples, were in general agreement between the STEM persistence and degree completion outcomes.

Multivariate Results by STEM Major Category

Next, we examined whether there were any notable differences in STEM college success rates overall and by student characteristics among the STEM major categories.[43] First, student profiles differed somewhat among the STEM major categories (Appendix D, Tables D1 and D2). Briefly, for both samples, a larger percentage of females majored in Medical & Health and Science than in Engineering & Technology and Computer Science & Mathematics. For the four-year sample, Medical & Health majors were generally the least likely to have taken higher-level and advanced high school coursework in mathematics and science, achieve an average ACT mathematics and science score of 26 or higher, and earn a HSGPA of 3.75 or higher. Group differences in these characteristics were smaller for the two-year sample. For both samples, Science majors were the most likely to have educational plans beyond a bachelor's degree, while the Computer Science & Mathematics majors were the most likely to have no interest in STEM. A larger percentage of the Engineering & Technology majors were at the more-selective four-year institutions.

Besides there being differences in the student profiles, STEM success rates also slightly differed among the STEM major categories (Appendix D, Tables D3 to D5; rates were evaluated at the typical [sample mean] values for the other student characteristics included in the models). For the four-year sample, majors in the Engineering & Technology category were more likely than majors in the other STEM categories to persist in STEM at year 4 and less likely to leave STEM and switch into a non-STEM major (Figure 3).

[43] STEM success rates by STEM major category were estimated by including STEM major category dummy variables in a total group model. Interaction terms between STEM major category and student characteristics were examined to evaluate whether the effects of the student characteristics on STEM success rates differed across the STEM categories.

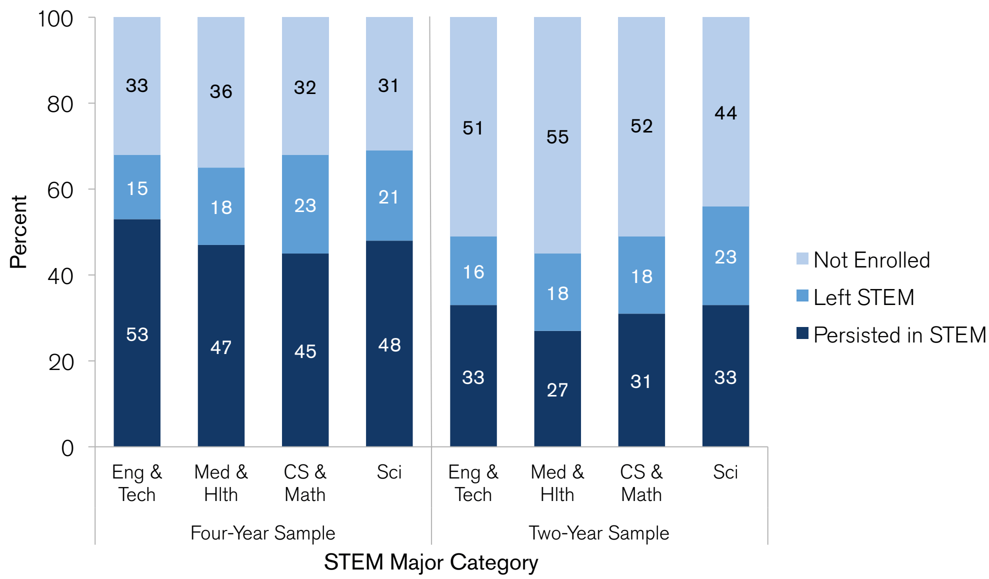

Figure 3. Modeled STEM persistence and attrition rates at year 4 by STEM major category

Among STEM persisters from the four-year sample, Medical & Health majors had the greatest chance of earning a cumulative GPA of 3.00 or higher at year 4 (73%) while Engineering & Technology majors had the smallest chance (51%). There was no overall difference in the typical STEM bachelor's degree completion rates among the STEM major categories (Table D5).[44] Moreover, for the four-year sample, 95% to 96% of STEM degree completers earned a degree in their initial STEM major category.

For the two-year sample, Medical & Health majors had the lowest STEM persistence and degree completion rates and were more likely to no longer be enrolled (Figure 3 and Tables D3 and D5). There was no difference in the cumulative GPA outcome among the STEM major categories (the rate ranged from 46% to 49% across major categories). Similar to results for the four-year sample, a majority of STEM degree completers in the two-year sample earned a degree in their initial STEM major category (85% for Science majors and 93% to 94% for the other major categories).[45]

For both the four- and two-year samples, we found that some of the relationships between the academic preparation and achievement characteristics and the likelihood of STEM success differed somewhat among the STEM major categories.[46] An example of this is illustrated in Figure 4, where the relationship between STEM persistence rates at year 4 and average ACT mathematics and science score slightly differed by STEM major category for the four-year sample. Specifically, a steeper curve was seen for students majoring in Medical & Health. These findings suggest that differences in STEM success rates among STEM major categories may depend upon the values of the other student characteristics taken into account. Despite some of these differences, from a

[44] As suggested by the empirical evidence for the four-year sample, the STEM major category effects were also included as random effects in the multivariate model. The variance estimates (and standard errors for these estimates) were 0.243 (0.086) for the Engineering & Technology indicator, 0.509 (0.139) for the Medical & Health indicator, and 0.162 (0.055) for the Computer Science & Mathematics indicator.

[45] Ten percent of STEM degree completers who initially declared a Science major earned a degree in a Medical & Health field.

[46] Interaction terms between student characteristics and STEM major category were used to evaluate whether there were differences in the relationships between student characteristics and the likelihood of STEM success among the STEM major categories.

practical perspective, the overall general conclusion from these comparisons suggest that, for each STEM major category, better academic preparation in mathematics and science was associated with greater chances of long-term STEM success (results for these comparisons not shown).

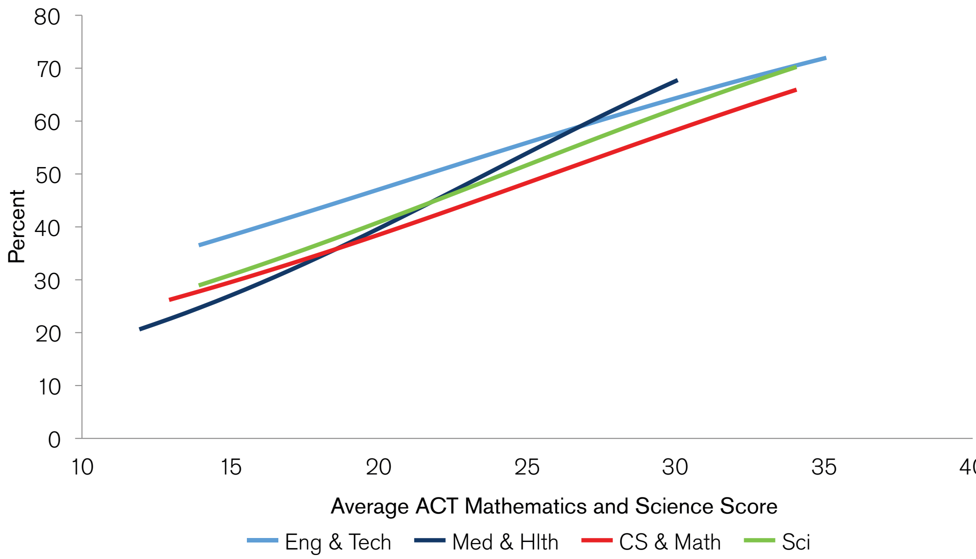

Figure 4. Modeled STEM persistence rates at year 4 by average ACT mathematics and science score and STEM major category for the four-year sample

Another common finding across the STEM major categories was that students with both expressed and measured STEM interests had higher STEM persistence and degree completion rates than students without STEM interests. Specifically, there was not a significant interaction between the four-category STEM interest grouping variable and STEM major category on predicting STEM success rates.[47] This finding held for both samples and for each outcome.

There were, however, some significant interaction effects on STEM success rates between STEM major category and student demographic characteristics. Below, we describe in detail the gender and racial/ethnic differences in STEM success rates among the STEM major categories. In some cases, these differences provide possible explanations for why there were some slight discrepancies in the overall four-year sample results between the STEM persistence and degree completion outcomes when the results were evaluated by gender and race/ethnicity.

First, for the overall four-year sample results, we found that STEM persistence rates at year 4 were comparable between female and male students, but that female students were slightly more likely than male students to complete a STEM degree. When these comparisons were examined by STEM major category, it was only among Medical & Health majors that female students had higher chances

[47] Based on students' intended majors, it was possible to not only look at whether students had an overall expressed interest in STEM (irrespective of the STEM major category; the measure used in this study), but also whether they had expressed interest in a specific STEM major category. In supplemental analyses, we examined whether agreement between the STEM major category of the expressed/intended major and declared major contributed additional information to predicting STEM success beyond the general four-category STEM interest grouping variable. Results suggested that this additional information added very little when included in the overall STEM models reported in Tables 6 to 10. However, when results were evaluated by STEM major category, this additional information helped to identify those who were likely to succeed in a STEM field among Computer Science & Mathematics majors only. For example, for Computer Science & Mathematics majors from the four-year sample, the STEM persistence rate at year 4 was 6 percentage points higher for students who intended to major in Computer Science & Mathematics than for those who did not (49% vs. 43%), after statistically controlling for all other variables shown in Table 6, including overall STEM interest.

than male students of persisting (49% vs. 39%, Figure 5) and completing a bachelor's degree in STEM (31% vs. 19% for six-year rate; adjusted OR = 1.8). This result was primarily due to male students in this major category being more likely than female students to no longer be enrolled. Among the other three STEM major categories, STEM persistence rates at year 4 and STEM degree completion rates were more similar between female and male students (adjusted ORs for STEM degree completion ranged from 1.0 to 1.1).

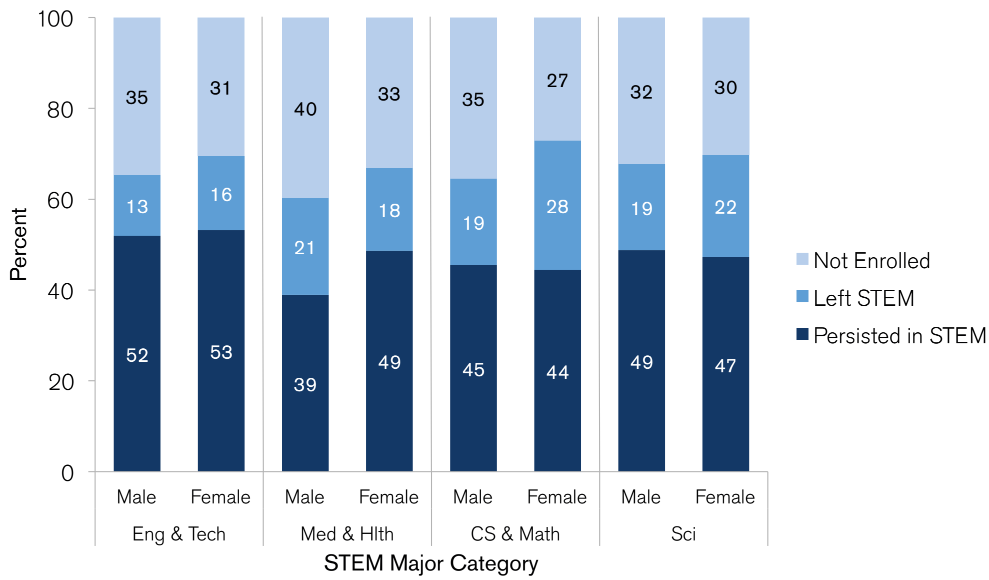

Figure 5. Modeled STEM persistence and attrition rates at year 4 by gender and STEM major category for the four-year sample

Another interesting observation from the comparisons shown in Figure 5 is that even though STEM persistence and degree completion rates were comparable between female and male students among Computer Science & Mathematics majors, female students were considerably more likely to leave STEM by switching into a non-STEM major (by 9 percentage points; adjusted OR = 1.5), while a greater percentage of male students were no longer enrolled (by 8 percentage points; adjusted OR = 0.8).

Despite the fact that there were no gender differences in STEM success rates for the overall two-year sample, the relationships between gender and the STEM persistence and degree completion outcomes differed among the STEM major categories. Specifically, a significant difference was found among Engineering & Technology majors for the two-year sample such that female students were less likely than male students to persist in STEM at year 4 (25% vs. 34%; Figure 6) and to complete an associate's or bachelor's degree in STEM (14% vs. 20% for the six-year rate; adjusted OR = 0.7). This finding was primarily due to female students in this major being more likely to leave STEM by switching into a non-STEM major.

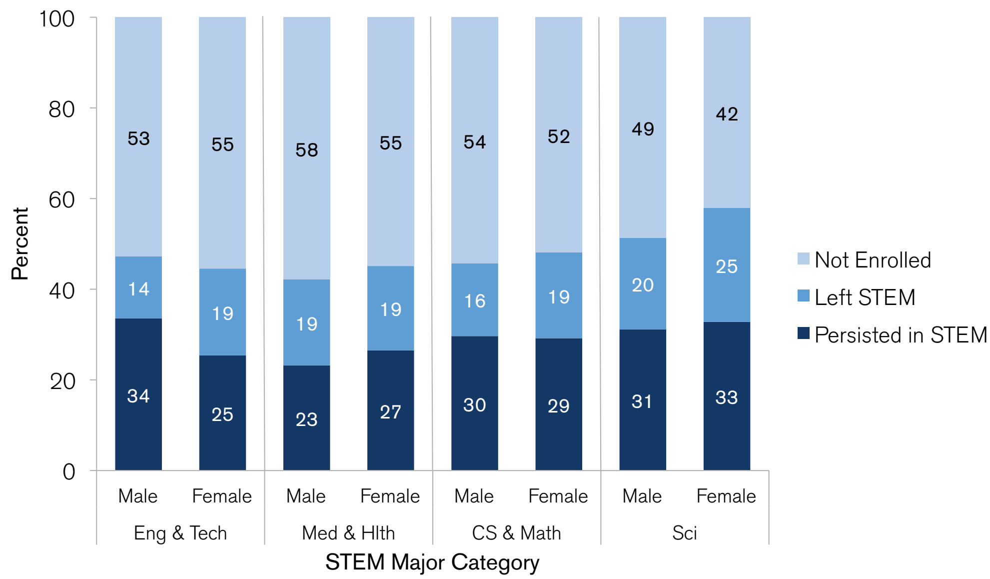

Figure 6. Modeled STEM persistence and attrition rates at year 4 by gender and STEM major category for the two-year sample

Another slight discrepancy in the overall four-year sample results was that even though STEM persistence rates at year 4 were comparable between underrepresented minority students and White/Asian students, underrepresented minority students were slightly less likely to complete a STEM degree. Similar to the corresponding gender analyses from the four-year sample, it was only among Medical & Health majors that underrepresented minority students were significantly less likely to persist in STEM at year 4 (39% vs. 49%; Figure 7) and to complete a STEM bachelor's degree (20% vs. 31%; adjusted OR = 0.6). Underrepresented minority students in this major were more likely to switch into a non-STEM major (adjusted OR = 1.6), as well as to no longer be enrolled (adjusted OR = 1.5).

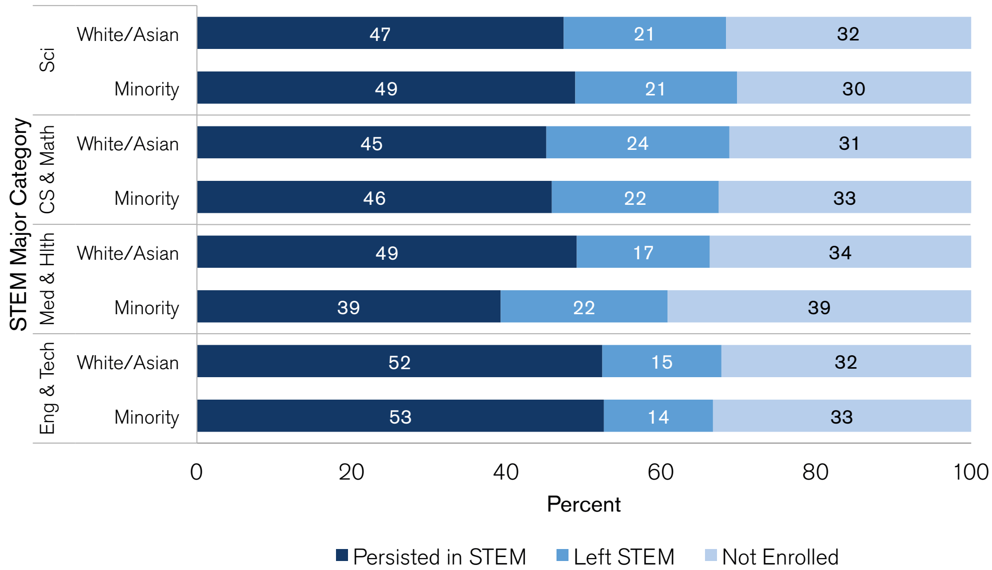

Figure 7. Modeled STEM persistence and attrition rates at year 4 by race/ethnicity and STEM major category for the four-year sample

In terms of the cumulative GPA outcome among STEM persisters, we found that underrepresented minority students were less likely than White/Asian students to earn a cumulative GPA of 3.00 or higher at year 4 for both the two-year and four-year samples. However, for the two-year sample, this relationship significantly differed among the STEM major categories. Specifically, for the two-year sample, it was only among Medical & Health majors and Science majors that significantly lower rates in the cumulative GPA outcome were seen for underrepresented minority students (adjusted OR = 0.5 and 0.6, respectively). This finding was not seen for Engineering & Technology majors and Computer Science & Mathematics majors (adjusted OR = 1.1 and 0.8, respectively).

Discussion

Corroborating previous findings (Chen, 2009; Chen, 2013; Chen & Ho, 2012), the current study underscores the fact that a large percentage of students who initially declare a STEM major in college switch to a non-STEM major or leave higher education prior to earning a degree in a STEM-related field. In terms of degree completion, it was estimated that less than a third of the four-year sample would earn a bachelor's degree in a STEM-related field within six years. For the two-year sample, the rate was even lower: It was estimated that only 19% would earn an associate's and/or bachelor's degree in a STEM-related field in the same timeframe. Moreover, many STEM majors had annual cumulative GPAs of less than a 3.00, which is one explanation for the high level of attrition observed in the current study.

Consistent with other research (Chen & Ho, 2012; Eagan et al., 2010; Maltese & Tai, 2011; Shaw & Barbuti, 2010), the current findings also highlight that STEM success rates varied markedly by various student characteristics. In particular, the current study identified pre-collegiate factors that could be used to identify students who have a high likelihood of achieving long-term success in a STEM major. In alignment with the Mattern et al. (2015) findings, the current study demonstrated that STEM majors better prepared in mathematics and science were more likely than those less prepared to persist in STEM through year 4, earn a cumulative GPA of 3.0 or higher over time, and complete a degree in a STEM field. For example, the estimated six-year STEM bachelor's degree completion rate for four-year students with an average ACT mathematics and science score of 26 or above was nearly twice as high (43%) compared to students with an average score of 22 or below (23%). This was also the case for students who earned higher HSGPAs. Though not as pronounced of an effect as for either ACT scores or HSGPA, taking higher-level mathematics and science courses was also be found to be related to STEM success.

The current study also supports the theory of person-environment fit as it relates to students' interests in STEM and subsequent success. The results indicate that after accounting for academic preparation and achievement and other student demographic characteristics, the highest STEM persistence and degree completion rates were observed for students with both expressed and measured STEM interest, whereas the lowest rates were observed for students who had neither expressed nor measured interest (e.g., 34% vs. 28%, respectively, for six-year STEM completion rates evaluated at the typical values for the other student characteristics included in the models). Though the effect was small compared to the results for cognitive predictors of STEM success, vocational interests provided incremental validity above and beyond academic achievement. The current findings are in agreement with previous research on the small yet statistically significant effect that interest-major fit has on students' likely success in college above cognitive ability (Allen & Robbins, 2010; Nye et al., 2012; Rounds & Su, 2014). For example, Allen and Robbins (2010) found that the effect of interest-major congruence was related to timely degree completion at four-year institutions, but that the effect was considerably smaller than that of first-year academic performance.[48]

When examining the results by STEM major category, it was consistently the case that being better prepared academically in mathematics and science and having STEM interest was associated with greater chances of long-term STEM success. Differences among the STEM major categories were also identified. The differences found in the modeled success rates were expected, given the differences in the academic profiles of students among the STEM major categories (ACT, 2014b). In particular, Medical & Health majors were the least prepared academically upon entrance into college. Additionally, they tended to be the least likely to be successful in terms of persisting and completing a degree in STEM, even after controlling for academic preparation and achievement and other student demographic characteristics.

The study also found that gender and racial/ethnic differences in STEM persistence and STEM degree completion depended on STEM major category and the sample (two- vs. four-year), though the overall gaps among racial/ethnic and family income groups were substantially reduced after accounting for academic preparation and interests. This latter finding is in alignment with a growing body of research documenting that much of the demographic subgroup differences in education outcomes are reduced and in some cases eliminated when prior preparation and education experiences are taken into account (Griffith, 2010). That said, the results indicated less reduction among family income groups, illustrating the additional obstacles that lower-income students often face, even among those who are better prepared academically for college (e.g., need to work and/or have family responsibilities; Engle & Tinto, 2008). Better understanding the barriers to college success for low-income students and determining those barriers that are unique to STEM majors

[48] The standardized regression coefficient for interest-major congruence was about one-fifth the size of the standardized effect for first-year cumulative GPA.

could help inform new initiatives and programs that are aimed at promoting STEM interest and success.

This study also found that female students in non-Medical & Health STEM majors were more likely than male students to switch to a non-STEM major. However, despite female students being somewhat more likely to leave STEM, they were in general slightly more likely than male students to remain enrolled and persist toward a degree. For example, the latter result was seen for seven out of the eight comparisons shown in Figures 5 and 6. Other research (DeAngelo, Franke, Hurtado, Pryor, & Tran, 2011; Ross, Kena, Rathbun, KewalRamani, Zhang, Kristapovich, & Manning, 2012) has also suggested that female students generally have higher persistence and degree completion rates overall. Future research should examine why females in STEM majors other than the Medical & Health major category tend to be more likely to switch to a non-STEM major. One potential explanation could be the "chilly climate" females experience when in a male-dominated major such as Engineering, potentially leading to feelings that one does not belong (Flam, 1991; Gayles & Ampaw, 2014; Walton, Logel, Peach, Spencer, & Zanna, 2014). Another possible explanation might be that females are more responsive to their higher grades earned in non-STEM courses than in STEM courses (Ost, 2010) or that female students are more likely to have an academic "plan B" in place. Another factor to consider is spatial ability.[49] Research has demonstrated that spatial ability is significantly related with academic and career success in what are currently identified as STEM fields (Andersen, 2014; Lubinski, 2010; Shea, Lubinski, & Benbow, 2001; Snow, 1999; Super & Baruch, 1957; Wai, Lubinski, & Benbow, 2009; Wood & Lebold, 1968). This may explain why males, who on average have higher levels of measured spatial ability than do females (Ackerman & Lohman, 2006; Bull, Cleland, & Mitchell, 2013; Casey, Nuttall, & Pezaris, 1997; Casey, Nuttall, Pezaris, & Benbow, 1995; Feingold, 1995; Hedges & Nowell, 1995; Maeda & Soon, 2013; Voyer, Voyer, & Bryden, 1995),[50] are more likely to enter certain STEM fields in college and why—after departing those STEM fields—males choose to leave school rather than earn a non-STEM degree.[51]

One limitation of the current study is that the sample is not nationally representative of all entering college STEM majors or institutions. As mentioned in the Methods section, most institutions were located in the North Central accrediting region. Additionally, nearly three-fourths of the four-year institutions and all of the two-year institutions were public institutions. Therefore, even though the current study employed large, multi-institutional samples of students and colleges, it is possible that the results could differ if more institutions from other parts of the US were included in the analyses. Furthermore, even though a substantial percentage of high school graduates in the two states included in the two-year sample take the ACT, the ACT test is generally not required for admission to two-year institutions; therefore, the two-year sample results may not generalize to the population

[49] Lohman (1994) noted that there are researchers who do not recognize the significance of spatial ability, and their perceptions may be due to the fact that the researchers themselves admit they are not visual thinkers. "Thus, if you do not experience vivid spatial imagery, then you may not understand the pervasive influence of such imagery in the lives of those who do experience it (p. 5)."

[50] Female students' spatial skills can be improved through experience and formal training (Chan, 2007; Spence, Yu, Feng, & Marshman, 2009). However, male students' spatial ability can be improved equally with training, though male and female growth patterns may differ (Martin-Dorta, Saorin, & Contero, 2008; Terlicki, Newcombe, & Little, 2008; Uttal et al., 2013).

[51] Spatially talented students can be identified before they go to college. Unfortunately, researchers have found that high school students with high mathematical and spatial abilities often have interests that are not well-aligned with traditional coursework, receive less college guidance while in high school, and end up undereducated relative to their overall ability, working in occupations that do not require a college education (Gohm, Humphreys, & Yao, 1998; Humphreys, Lubinski, & Yao, 1993). Furthermore, our current education and assessment system concentrates on verbal and quantitative abilities and ignores spatial ability (Andersen, 2014; Gohm et al., 1998; Humphreys et al., 1993; Lubinski, 2010; Stumpf, Mills, Brody, & Baxley, 2013). Given that many of these mathematically and spatially talented students are turned off by traditional coursework in high school, those who survive the K–12 system only to depart from a STEM program in college may have little if any interest in the plethora of non-STEM majors that emphasize verbal skills.

of entering STEM majors at two-year schools that may include older, non-traditional students, as well as traditional students who did not take the ACT. The inability to completely differentiate between student transfer and dropout and their effects on STEM outcomes was another study limitation.[52] Additionally, it is worth mentioning that interest-major fit is just one small aspect of person-environment fit. There is a wide range of personal attributes, such as values, skills, and family expectations, pervasive in people's lives that contribute to person-environment fit that were not measured in this study. Other psychosocial characteristics, like academic discipline, motivation, and study habits, that have been shown to effect timely degree completion beyond first-year academic performance and interest-major congruence (Allen & Robbins, 2010) were also not available in the current study. Future research should address such concerns.

In conclusion, results from this study suggest that new initiatives and programs aimed at promoting STEM interest and participation among US students must also be focused on helping students to prepare academically for the rigorous demands of STEM coursework, and that this preparation needs to take place prior to college enrollment. Prior research indicates that students who are off-track academically in eighth grade (including in the STEM-related subject areas of mathematics and science) are unlikely to get on track (in these subject areas) by the end of high school (ACT, 2008; Bassiri, 2014; Dougherty, 2014). Policymakers and educators can help students to prepare academically for STEM-related coursework by (1) monitoring student progress to STEM readiness early and often, and intervening with students who do not seem to be on track, especially among those interested in pursuing STEM-related majors and careers and (2) ensuring students have access to rigorous higher-level mathematics and science coursework in high school, including exposure to Calculus-related concepts. For example, for the former, STEM readiness can be monitored over time using the ACT Aspire® assessment system and the ACT STEM score (Radunzel, Mattern, Crouse, & Westrick, 2015; Yi, He, Tao, & Fang, 2016). This information can be used to help align students' expectations with future course demands in STEM-related areas.

Additionally, given the importance of academic behaviors and other noncognitive characteristics such as motivation, academic discipline, self-regulation for success in college (ACT, 2012; Conley, 2007; Mattern et al., 2014), students interested in majoring in STEM fields need to develop strong academic behaviors, particularly given the heavier academic load (e.g., course difficulty) and the resulting increased time commitments associated with many STEM majors (Drew, 2011; Goldman, Schmidt, Hewitt, & Fisher, 1974). In terms of academic and career advising, it is important to also provide students with educational and career guidance early and often. The goal of educational and career guidance programs should be to encourage students to (1) explore career and college options that are a good match with their individual strengths, interests, and values and (2) acquire the skills and information that is needed to successfully navigate their educational and career goals (Bobek & Zhao, 2015). There is a great deal of empirical research showing the importance of interest-major fit on subsequent academic as well as occupation success (e.g., Allen & Robbins, 2010; Rounds & Su, 2014). Results from the current study also support this, given that students with expressed and measured interests in STEM were found to be more likely than those with no interest to persist and complete a STEM degree. ■

[52] Our inability to differentiate between student dropout and transfer may also explain why the percentage of students no longer enrolled without a degree in this study was higher than that reported by Chen (2013) and why the percentage of students leaving STEM and switching into a non-STEM major was lower.

References

Ackerman, P. L. & Lohman D. F. (2006). Individual differences in cognitive functions. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology, 2nd edition* (pp. 139–161). Mahwah, NJ: Erlbaum.

ACT, Inc. (1995). *Technical manual: Revised unisex edition of the ACT Interest Inventory (UNIACT).* Iowa City, IA: ACT.

ACT. (2008). *The forgotten middle: Ensuring that all students are on target for college and career readiness before high school*. Iowa City, IA: ACT.

ACT. (2009). *The ACT Interest Inventory technical manual.* Iowa City, IA: ACT.

ACT (2012). *ACT Engage® user's guide*. Iowa City, IA: ACT.

ACT. (2014a). *Technical Manual: The ACT®.* Iowa City, IA: ACT.

ACT. (2014b). *The Condition of STEM 2013.* Iowa City, IA: ACT.

ACT. (2014c). *The Condition of STEM 2014.* Iowa City, IA: ACT.

ACT. (2015). *The Condition of STEM 2015.* Iowa City, IA: ACT.

Allen, J. (2013). *Updating the ACT College Readiness Benchmarks*. (ACT Research Report 2013-6). Iowa City, IA: ACT.

Allen, J., & Robbins, S. (2010). Effects of interest-major congruence, motivation, and academic performance on timely degree attainment. *Journal of Counseling Psychology,* 57(1), 23–35.

Allison, P. D. (1995). *Survival analysis using SAS®: A practical guide.* Cary, NC: SAS Institute Inc.

Andersen, L. (2014). Visual–Spatial Ability: Important in STEM, Ignored in Gifted Education. *Roeper Review*, *36*(2), 114–121.

Anderson, E., & Kim, D. (2006). *Increasing the success of minority students in science and technology.* Washington, DC: American Council on Education.

Bassiri, D. (2014). *Research study: The forgotten middle.* Iowa City, IA: ACT.

Beede, D., Julian, T., Langdon, D., McKittrick, G., Khan, B., and Doms, M. (2011). *Women in STEM: A gender gap to innovation* (ESA Issue Brief 04-11). Washington, DC: US Department of Commerce.

Bowen, W. G., Chingos, M. M., & McPherson, M. S. (2009). *Crossing the finish line: Completing college at America's public universities*. Princeton, NJ: Princeton University Press.

Bobek. B., & Zhao, R. (2015). Education and career navigation. In *Beyond academics: A holistic framework for enhancing education and workplace success* (ACT Research Report 2015-4, pp. 39–51), edited by W. Camara, R. O'Connor, K. Mattern, and M. A. Hanson. Iowa City, IA: ACT.

Bull, R., Cleland, A. A., & Mitchell, T. (2013). Sex differences in the spatial representation of number. *Journal of Experimental Psychology: General*, *142*(1), 181–192.

Carnevale, A. P., Smith, N., & Melton, M. (2011). *STEM: Science, Technology, Engineering, and Mathematics.* Washington, DC: Center on Education and the Workforce, Georgetown University.

Casey, M. B., Nuttall, R. L., & Pezaris, E. (1997). Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology*, *33*(4), 669–680.

Casey, M. B., Nuttall, R., Pezaris, E., & Benbow, C. P. (1995). The influence of spatial ability on gender differences in mathematics college entrance test scores across diverse samples. *Developmental Psychology*, *31*(4), 697–705. doi:10.1037/0012-1649.31.4.697

Chan, D. W. (2007). Gender differences in spatial ability: Relationship to spatial experience among Chinese gifted students in Hong Kong. *Roeper Review*, *29*(4), 277–282.

Chen, X. (2009). *Students who study science, technology, engineering, and mathematics (STEM) in postsecondary education* (NCES 2009-161). National Center for Education Statistics. Washington, DC: US Department of Education.

Chen, X. (2013). *STEM Attrition: College students' paths into and out of STEM fields.*

Statistical analysis report (NCES 2014-001). National Center for Education Statistics. Washington, DC: US Department of Education.

Chen, X., & Ho, P. (2012). *STEM in postsecondary education: Entrance, attrition, and coursetaking among 2003–04 beginning postsecondary students* (NCES 2013-152). National Center for Education Statistics. Washington, DC: US Department of Education.

Conley, D. T. (2007). *Redefining college readiness*. Eugene, OR: Educational Policy Improvement Center.

Dawis, R. V., & Lofquist, L. H. (1984). *A psychological theory of work adjustment: An individual-differences model and its applications*. Minneapolis, MN: University of Minnesota Press.

DeAngelo, L., Franke, R., Hurtado, S., Pryor, J.H., & Tran, S. (2011). *Completing college: Assessing graduation rates at four-year institutions.* Los Angeles, CA: Higher Education Research Institute, UCLA.

Dougherty, C. (2014). *Catching up to college and career readiness: The challenge is greater for at-risk students* (ACT Issue Brief). Iowa City, IA: ACT.

Drew, C. (2011, November 4). Why science majors change their minds (it's just so darn hard). *The New York Times*. Retrieved on April 20, 2015 from www.nytimes.com/2011/11/06/education/edlife/why-science-majors-change-their-mind-its-just-so-darn-hard.html?.

Eagan, K., Hurtado, S., & Chang, M. (2010). *What matters in STEM: Institutional contexts that influence STEM bachelor's degree completion rates.* Indianapolis, IN: Association for the Study of Higher Education (ASHE).

Engle, J., & Tinto, V. (2008). *Moving beyond access: College success for low-income, first-generation students.* Washington, DC: The Pell Institute.

Executive Office of the President, President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* Retrieved from www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf.

Feingold, A. (1995). The additive effects of differences in central tendency and variability are important in comparisons between groups. *American Psychologist*, *50*(1), 5–13.

Flam, F. (1991). Still a 'chilly climate' for women? *Science, 252,* 1604–1606.

Gayles, J. G., & Ampaw, F. (2014). The impact of college experiences on degree completion in STEM fields at four-year institutions: Does gender matter? *The Journal of Higher Education, 85*(4), 439–468.

Gohm, C. L., Humphreys, L. G., & Yao, G. (1998). Underachievement among spatially gifted students. *American Educational Research Journal*, *35*(3), 515–531. doi:10.2307/1163447

Goldman, R. D., Schmidt, D. E., Hewitt, B. N., & Fisher, R. (1974). Grading practices in different major fields. *American Education Research Journal, 11*(4), 343–357.

Government Accountability Office (GAO). (2012). *Science, technology, engineering, and mathematics education: Strategic planning needed to better manage overlapping programs across multiple agencies* (GAO-12-108). Washington, DC: GAO.

Green, M. (2007). *Science and Engineering Degrees: 1966-2004* (NSF 07-307). Arlington, VA: National Science Foundation.

Griffith, A.L. (2010). *Persistence of women and minorities in STEM field majors: Is it the school that matters?* Retrieved April 20, 2015 from Cornell University, School of Industrial and Labor relations site: digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?article=1137&context=workingpapers.

Hedges, L. V., & Nowell, A. (1995). Sex differences in mental test scores, variability, and numbers of high-scoring individuals. *Science*, *269*(5220), 41–45.

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments*. (3rd ed.). Odessa, FL: Psychological Assessment Resources.

Humphreys, L. G., Lubinski, D., & Yao, G. (1993). Utility of predicting group membership and the role of spatial visualization in becoming an engineer, physical scientist, or artist. *Journal of Applied Psychology*, *78*(2), 250–261. doi: 10.1037/0021-9010.78.2.250

Kokkelenberg, E. C., & Sinha, E. (2010). Who succeeds in STEM studies? An analysis of Binghamton University undergraduate students. *Economics of Education Review, 29*(6)*,* 935–946.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *STEM: Good jobs now and for the future* (US Department of Commerce, Economics and Statistics Administration Issue Brief 03-11). Retrieved from www.esa.doc.gov/sites/default/files/stemfinalyjuly14_1.pdf.

Le, H., Robbins, S. B., & Westrick, P. (2014). Predicting student enrollment and persistence in college STEM fields using an expanded P-E fit framework: A large-scale multilevel study. *Journal of Applied Psychology, 99*(5), 915–947.

Lohman, D. F. (1994). Spatially gifted, verbally inconvenienced. In N. Colangelo, S. G. Assouline, & D. L. Ambroson (Eds.), *Talent development: Vol. 2. Proceedings from the 1993 Henry B. and Jocelyn Wallace National Research Symposium on Talent Development* (pp. 251–264). Dayton, OH: Ohio Psychology Press.

Lubinski, D. (2010). Spatial ability and STEM: A sleeping giant for talent identification and development. *Personality and Individual Differences*, *49*(4), 344–351. doi:10.1016/j.paid.2010.03.022

Maeda, Y., & Yoon, S. Y. (2013). A meta-analysis on gender differences in mental rotation ability measured by the Purdue spatial visualization tests: Visualization of rotations (PSVT: R). *Educational Psychology Review*, *25*(1), 69–94.

Maltese, A.V., & Tai, R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, *95*(5), 877–907.

Martín-Dorta, N., Saorín, J. L., & Contero, M. (2008). Development of a fast remedial course to improve the spatial abilities of engineering students. *Journal of Engineering Education*, *97*(4), 505–513.

Mattern, K., Burrus, J., Camara, W., O'Connor, R., Hansen, M. A., Gambrell, J., Casillas, A., & Bobek, B. (2014). *Broadening the definition of college and career readiness: A holistic approach* (ACT Research Report 2014-5). Iowa City, IA: ACT.

Mattern, K., Radunzel, J., & Westrick, P. (2015). *Development of STEM Readiness Benchmarks to Assist Career and Educational Decision Making* (ACT Research Report 2015-3). Iowa City, IA: ACT.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (ed.), *Frontiers in Econometrics* (pp. 105–142). Cambridge, MA: Academic Press.

National Science Board. (2014). *Science and Engineering Indicators 2014: Appendix Tables*. Arlington, VA: National Science Foundation (NSB 14-01).

Nye, C. D., Su, R., Rounds, J., & Drasgow, F. (2012). Vocational interests and performance: A quantitative summary of over 60 years of research. *Perspectives on Psychological Science*, *7*(4), 384–403.

Ost, B. (2010). The role of peers and grades in determining major persistence in the sciences. *Economics of Education Review, 29*(6), 923–934.

Radunzel, J., Mattern, K., Crouse, J., & Westrick, P. (2015). *Development and validation of a STEM benchmark based on the ACT STEM score* (ACT Technical Brief). Iowa City, IA: ACT.

Reardon, S. F., Brennan, R. T., & Buka, S. L. (2002). Estimating multi-level discrete-time hazard models using cross-sectional data: Neighborhood effects on the onset of adolescent cigarette use. *Multivariate Behavioral Research, 37*(3), 297–330.

Ross, T., Kena, G., Rathbun, A., KewalRamani, A., Zhang, J., Kristapovich, P., and Manning, E. (2012). *Higher education: Gaps in access and persistence study* (NCES 2012-046). National Center for Education Statistics. Washington, DC: US Department of Education.

Rounds, J., Smith, T., Hubert, L., Lewis, P., & Rivkin, D. (1999). *Development of occupational interest profiles for O_NET* [Electronic Version]. Available from www.onetcenter.org/dl_files/OIP.pdf.

Rounds, J., & Su, R. (2014). The nature and power of interests. *Current Directions in Psychological Science, 23*(2), 98–103.

Sanchez, E., & Buddin, R. (2016). *How accurate are self-reported high school courses, course grades, and grade point average?* (ACT Research Report 2016-3). Iowa City, IA: ACT.

Shapiro, D., Dundar, A., Ziskin, M., Chiang, Y., Chen, J., Torres, V., & Harrell, A. (2013). *Baccalaureate attainment: A national view of the postsecondary outcomes of students who transfer from two-year to four-year institutions* (Signature Report 5). Herndon, VA: National Student Clearinghouse Research Center.

Shaw, E. J., & Barbuti, S. (2010). Patterns of persistence in intended college major with a focus on STEM majors. *The National Academic Advising Association Journal*, *30*(2), 19–34.

Shaw, E. J., & Mattern, K. D. (2009). *Examining the accuracy of self-reported high school grade point average* (College Board Research Report 2009-5). New York, NY: College Board.

Shea, D. L., Lubinski, D., & Benbow, C. P. (2001). Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology, 93*(3), 604–614.

Singer, J. D., & Willett, J. B. (1993). It's about time: Using discrete-time survival analysis to study duration and the timing of events. *Journal of Educational and Behavioral Statistics, 18*(2), 155–195.

Snow, R. E. (1999). Commentary: Expanding the breadth and depth of admissions testing. In S. Messick (Ed.), *Assessment in higher education: Issues of access, quality, student development, and public policy* (pp. 133–140). Mahwah, NJ: Erlbaum.

Spence, I., Yu, J. J., Feng, J., & Marshman, J. (2009). Women match men when learning a spatial skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(4), 1097–1103.

Stumpf, H., Mills, C. J., Brody, L. E., & Baxley, P. G. (2013). Expanding talent search procedures by including measures of spatial ability: CTY's spatial test battery. *Roeper Review*, *35*(4), 254–264.

Super, D. E., & Bachrach, P. B. (1957). *Scientific careers and vocational development theory*. New York, NY: Teachers College, Columbia University.

Terlecki, M. S., Newcombe, N. S., & Little, M. (2008). Durable and generalized effects of spatial experience on mental rotation: Gender differences in growth patterns. *Applied Cognitive Psychology, 22*(7), 996–1013. doi:10.1002/acp.1420

US Department of Labor. (2007). *The STEM workforce challenge: The role of the public workforce system in a national solution for a competitive science, technology, engineering, and mathematics (STEM) workforce*. Retrieved from www.doleta.gov/youth_services/pdf/STEM_Report_4%2007.pdf.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, *139*(2), 352–402.

Venkataraman, B., Riordan, D. G., & Olson, S. (2010). *Prepare and inspire: K–12 education in science, technology, engineering, and math (STEM) for America's future*. Washington, DC: President's Council of Advisors on Science and Technology.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*(2), 250–270

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*(4), 817–835. doi: 10.1037/a0016127

Walton, G. M., Logel, C., Peach, J. M., Spencer, S. J., & Zanna, M. P. (2014). Two brief interventions to mitigate a "chilly climate" transform women's experience, relationships, and achievement in engineering. *Journal of Educational Psychology, 107*(2), 468–485. doi: 10.1037/a0037461

Westrick, P. (2014). *Average ACT mathematics scores for quantitative science majors* (ACT Information Brief 2014-20). Iowa City, IA: ACT.

White House, Office of the Press Secretary. (2009). President Obama Launches "Educate to Innovate" Campaign for Excellence in Science, Technology, Engineering & Math (STEM) Education. Retrieved from www.whitehouse.gov/the-press-office/president-obama-launches-educate-innovate-campaign-excellence-science-technology-en.

Wood, D. A., & Lebold, W. K. (1968). Differential and overall prediction of academic success in engineering: The complementary role of DAT, SAT and HSR. *Educational and Psychological Measurement*, *28*(4), 1223–1228.

Yi, Q., He, Y., Tao, W., & Fang, Y. (2016). *Updating ACT Aspire® STEM readiness benchmarks* (ACT Technical Brief). Iowa City, IA: ACT.

Appendix A—STEM Major Category CIP Codes

Table A1. STEM Major Category CIP Codes

STEM Major Category	CIP Codes
Engineering & Technologies	14, 15, 28, 29, 0402, 0408 to 0410, 0499, 5220
Computer Science & Mathematics	11[1], 27, 131311, 5212, 5213
Medical & Health	1905, 5101, 5104, 5105, 5110, 5112, 5114, 5117 to 5120, 5124, 5125, 5138, 5139, 510808, 510904, 510905, 510907 to 510909, 510911 to 510913, 511101 to 511106, 511108, 511109, 512308
Science	26, 40, 41, 0109 to 0112, 0301 to 0303, 0305, 0306, 0399,131316, 131322, 131323, 131329, 131337, 131338

Note: The two- and four-digit CIP codes encompass all codes under them in the hierarchy. For more information on specific CIP codes, go to the National Center for Education Statistics website at nces.ed.gov/ipeds/cipcode/Default.aspx?y=55.

[1] Excludes six-digit CIP code 110803 (Computer Graphics).

Appendix B—Variability Estimates from the Hierarchical Models

Tables B1 through B3

Table B1. Random Intercept Variance Estimates for STEM Persistence at Year 4 Outcome by Study Sample

	Not Enrolled vs. Persisted in STEM				Left STEM vs. Persisted in STEM			
			Range Across Institutions				Range Across Institutions	
Model	Variance Estimate	Standard Error	Min	Max	Variance Estimate	Standard Error	Min	Max
Four-Year Sample								
Null	0.500	0.104	-1.720	1.214	1.131	0.256	-6.000	0.192
Multivariate	0.126	0.028	-0.920	0.777	0.881	0.205	-4.269	0.862
Two-Year Sample								
Null	0.108	0.033	-0.027	1.225	0.109	0.035	-1.500	-0.037
Multivariate	0.068	0.024	-0.678	0.341	0.111	0.038	-0.921	0.458

Note: The multivariate model includes the student and institutional characteristics presented in Tables 6 and C1 for the four-year sample and in Tables 7 and C1 for the two-year sample (except advanced high school coursework in science was not included in two-year sample model). The student and institutional characteristics were grand mean centered in the models. The intraclass correlation coefficients for the four-year sample were estimated to be 0.13 for the not enrolled vs. persisted outcome and 0.26 for the left STEM vs. persisted outcome. The corresponding values for the two-year sample were 0.03 and 0.03, respectively.

Table B2. Random Intercept Variance Estimates for Chances of Earning a 3.00 or Higher Cumulative GPA at Year 4 Outcome by Study Sample

			Range Across Institutions	
Model	Variance Estimate	Standard Error	Min	Max
Four-Year Sample				
Null	0.236	0.056	-1.313	1.088
Multivariate	0.084	0.024	-0.566	0.446
Two-Year Sample				
Null	0.206	0.076	-0.767	0.836
Multivariate	0.215	0.076	-0.549	1.101

Note: The multivariate model includes the student and institutional characteristics presented in Tables 8 and C2 for the four-year sample with the exceptions of highest science course and advanced high school coursework in science. For the two-year sample, the model included race/ethnicity, advanced high school coursework in mathematics, average ACT mathematics and science score, and HSGPA. The student and institutional characteristics were grand mean centered in the models. The intraclass correlation coefficient was estimated to be 0.07 for the four-year sample and 0.06 for the two-year sample.

Table B3. Random Intercept and Slope Variance Estimates for STEM Degree Completion Outcome by Study Sample

	Four-Year Sample		Two-Year Sample	
Variable	Null Model Estimate (SE)	Multivariate Model Estimate (SE)	Null Model Estimate (SE)	Multivariate Model Estimate (SE)
Term 4	—	—	1.323 (0.395)	1.225 (0.387)
Term 5	—	—	—	—
Term 6	0.488 (0.154)	0.437 (0.138)	0.301 (0.102)	0.278 (0.102)
Term 7	0.700 (0.206)	0.668 (0.205)	—	—
Term 8	0.880 (0.193)	0.379 (0.088)	0.250 (0.094)	0.305 (0.115)
Term 9	0.642 (0.157)	0.360 (0.099)	—	—
Term 10	0.603 (0.143)	0.294 (0.078)	0.159 (0.079)	0.092 (0.070)
Term 11	0.508 (0.166)	0.468 (0.154)	—	—
Term 12	0.290 (0.094)	0.259 (0.095)	0.205 (0.159)	0.152 (0.162)
Gender	—	0.053 (0.018)	—	0.193 (0.082)
Overall HSGPA				
≥ 3.75 vs. < 3.30	—	0.053 (0.022)	—	—
3.30 to 3.74 vs. < 3.30	—	0.014 (0.013)	—	—
Average ACT Mathematics and Science				
≥ 26 vs. ≤ 22	—	0.034 (0.015)	—	—
22.5 to 25.5 vs. ≤ 22	—	0.013 (0.009)	—	—

Note: The multivariate model includes the student and institutional characteristics presented in Tables 9 and C3 for the four-year sample and in Tables 10 and C3 for the two-year sample (except advanced high school coursework in science was not included in two-year sample model). The student and institutional characteristics were grand mean centered in the models. The intraclass correlation coefficients for the conditional probabilities of completing a degree within a specific term given that no degree was earned prior to that term ranged from 0.08 (for term 12) to 0.21 (for term 8) for the four-year sample and from 0.05 (for term 10) to 0.29 (for term 4) for the two-year sample.

Appendix C—Multivariate Results by Student Demographic Characteristics

Tables C1 through C3

Table C1. Multivariate Results for STEM Persistence at Year 4, by Student Demographics and Study Sample

	Estimated Rates			Not Enrolled vs. Persisted in STEM			Left STEM vs. Persisted in STEM		
Student Characteristics	Not Enrolled	Left STEM	Persisted in STEM	OR	95% CI		OR	95% CI	
Four-Year Sample									
Gender									
Male	34	18	48						
Female	31	21	48	0.91	0.87	0.96	1.21	1.15	1.27
Race/Ethnicity									
Minority	33	20	47	1.06	0.99	1.13	1.06	0.99	1.13
Other/Multiracial	35	16	49	1.07	0.97	1.18	0.82	0.73	0.93
White/Asian	32	19	48						
Income									
< $36,000	39	18	43						
$36,000 to $80,000	33	19	48	0.77	0.73	0.81	0.98	0.92	1.05
> $80,000	28	20	52	0.60	0.56	0.64	0.97	0.90	1.04
Two-Year Sample									
Gender									
Male	53	16	31						
Female	52	20	29	1.05	0.95	1.16	1.29	1.14	1.46
Race/Ethnicity									
Minority	56	16	28	1.23	1.10	1.38	0.97	0.84	1.12
Other/Multiracial	56	19	25	1.39	1.12	1.73	1.27	0.98	1.65
White/Asian	50	19	31						
Income									
< $36,000	57	16	27						
$36,000 to $80,000	50	19	31	0.75	0.68	0.83	0.99	0.87	1.13
> $80,000	45	22	33	0.62	0.54	0.72	1.07	0.90	1.27

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in Table 6 (except for advanced high school coursework in science and institution selectivity for the two-year sample), as well as for gender, race/ethnicity, and family income range. OR = odds ratio; CI = confidence interval.

Table C2. Multivariate Results for STEM Persisters' Chances of Earning a 3.00 or Higher Cumulative GPA at Year 4, by Student Demographics and Study Sample

	Four-Year Sample					Two-Year Sample				
Student Characteristic	N	Rate	OR	95% CI		N	Rate	OR	95% CI	
Gender										
Male	14,034	54				1,702	46			
Female	12,623	68	1.81	1.69	1.94	1,840	49	1.13	0.96	1.32
Race/Ethnicity										
Minority	5,009	52	0.61	0.56	0.67	746	41	0.68	0.57	0.82
Other/Multiracial	2,722	62	0.89	0.78	1.02	2,603	47	0.89	0.67	1.17
White/Asian	19,766	64				259	50			
Income										
< $36,000	5,766	56				1,237	48			
$36,000 to $80,000	11,519	62	1.31	1.21	1.42	1,744	48	0.94	0.76	1.17
> $80,000	10,212	65	1.49	1.36	1.63	627	47	0.97	0.82	1.14

Note: Italics indicate referent group. For the four-year sample, adjustment was made for all student characteristics included in Table 8 (except for highest science course and advanced high school coursework in science), as well as gender, race/ethnicity, and family income range. For the two-year sample, adjustment was made for race/ethnicity, advanced high school coursework in mathematics, average ACT mathematics and science score, and HSGPA. OR = odds ratio; CI = confidence interval.

Table C3. Multivariate Results for STEM Degree Completion, by Student Demographics and Study Sample

	Estimated Rates					
Student Characteristics	Year 4	Year 5	Year 6	OR	95% CI	
Four-Year Sample—Bachelor's Degree Completion						
Gender						
Male	15	26	30			
Female	17	29	33	1.12	1.02	1.22
Race/Ethnicity						
Minority	15	25	29	0.88	0.83	0.93
Other/Multiracial	17	29	33	1.02	0.94	1.10
White/Asian	17	28	32			
Income						
< $36,000	14	24	27			
$36,000 to $80,000	16	28	32	1.21	1.15	1.27
> $80,000	18	31	35	1.40	1.33	1.48
Two-Year Sample—Associate's or Bachelor's Degree Completion						
Gender						
Male	12	16	18			
Female	11	14	16	0.88	0.72	1.07
Race/Ethnicity						
Minority	10	13	15	0.82	0.73	0.93
Other/Multiracial	10	12	14	0.77	0.61	0.97
White/Asian	12	16	18			
Income						
< $36,000	10	13	15			
$36,000 to $80,000	13	16	18	1.30	1.17	1.44
> $80,000	13	16	19	1.31	1.14	1.51

Note: Italics indicate referent group. Adjustment was made for all student characteristics included in Table 9 (except for advanced high school coursework in science and institution selectivity for the two-year sample), as well as for gender, race/ethnicity, and family income range. OR = odds ratio; CI = confidence interval.

Appendix D—Results by STEM Major Category

Tables D1 through D5

Table D1. Description of Student Characteristics by STEM Major Category for Four-Year Sample

	Engineering & Technology (N = 16,387)		Medical & Health (N = 13,345)		Computer Science & Mathematics (N = 8,214)		Science (N = 25,144)	
Student Characteristic	*n*	Percent	*n*	Percent	*n*	Percent	*n*	Percent
Gender								
Male	12,397	78	2,444	19	5,521	69	10,513	43
Female	3,430	22	10,662	81	2,488	31	13,930	57
Race/Ethnicity								
Minority	2,974	18	3,157	24	2,116	26	5,497	22
Other/Multiracial	1,752	11	864	6	740	9	2,381	9
White/Asian	11,661	71	9,324	70	5,358	65	17,266	69
Annual Family Income								
< $36,000	3,178	19	4,412	33	2,466	30	6,332	25
$36,000 to $80,000	6,702	41	5,807	44	3,333	41	10,736	43
> $80,000	6,507	40	3,126	23	2,415	29	8,076	32
Highest Mathematics Course								
Calculus	6,128	37	1,756	13	2,193	27	6,602	26
Trig/Other Advanced Mathematics	7,144	44	6,797	51	3,780	46	12,081	48
Algebra II	2,882	18	495	4	215	3	497	2
Below Algebra II	233	1	4,297	32	2,026	25	5,964	24
Highest Science Course								
Physics	9,599	59	3,523	26	3,596	44	10,693	43
Chemistry	5,449	33	7,508	56	3,581	44	11,909	47
Biology or Below	1,339	8	2,314	17	1,037	13	2,542	10
Advanced HS Mathematics Coursework								
No	3,323	20	6,103	46	2,609	32	7,392	29
Yes	13,064	80	7,242	54	5,605	68	17,752	71
Advanced HS Science Coursework								
No	4,391	27	6,303	47	3,249	40	7,822	31
Yes	11,996	73	7,042	53	4,965	60	17,322	69
Average ACT Mathematics and Science Score								
≤ 22	3,646	22	8,892	67	3,246	40	10,113	40
22.5 to 25.5	4,569	28	3,110	23	2,325	28	7,494	30
≥ 26	8,172	50	1,343	10	2,643	32	7,537	30
HSGPA								
< 3.30	3,519	21	4,812	36	2,636	32	5,876	23
3.30 to 3.74	4,739	29	4,117	31	2,410	29	7,434	30
≥ 3.75	8,129	50	4,416	33	3,168	39	11,834	47

Table D1. (continued)

Student Characteristic	Engineering & Technology (N = 16,387)		Medical & Health (N = 13,345)		Computer Science & Mathematics (N = 8,214)		Science (N = 25,144)	
	n	Percent	*n*	Percent	*n*	Percent	*n*	Percent
Selectivity of Institution Attended								
Less-Selective	5,188	32	9,665	72	4,604	56	13,197	52
Selective	11,199	68	3,680	28	3,610	44	11,947	48
Educational Plans								
Bachelor's or Below	5,746	35	5,792	43	3,723	45	5,982	24
Beyond Bachelor's	10,641	65	7,553	57	4,491	55	19,162	76
STEM Interest								
Expressed and Measured	4,220	34	3,162	29	1,354	21	8,809	44
Expressed Only	5,482	44	4,243	38	2,574	40	5,735	29
Measured Only	733	6	916	8	506	8	2,038	10
No Interest	1,952	16	2,733	25	1,997	31	3,511	17

Note: Gender and STEM interest percentages based on respondents only.

Table D2. Description of Student Characteristics by STEM Major Category for Two-Year Sample

	Engineering & Technology (N = 3,224)		Medical & Health (N = 5,661)		Computer Science & Mathematics (N = 1,684)		Science (N = 2,260)	
Student Characteristic	*n*	Percent	*n*	Percent	*n*	Percent	*n*	Percent
Gender								
Male	2,373	75	1,167	21	1,211	73	922	42
Female	789	25	4,392	79	443	27	1,293	58
Race/Ethnicity								
Minority	714	22	1,438	25	468	28	621	27
Other/Multiracial	292	9	374	7	131	8	204	9
White/Asian	2,218	69	3,849	68	1,085	64	1,435	64
Annual Family Income								
< $36,000	1,095	34	2,461	43	698	41	867	38
$36,000 to $80,000	1,515	47	2,460	43	741	44	1,040	46
> $80,000	614	19	740	13	245	15	353	16
Highest Mathematics Course								
Calculus	301	9	319	6	126	7	195	9
Trig/Other Advanced Mathematics	1,183	37	2,308	41	682	41	935	41
Algebra II	1,475	46	2,607	46	736	44	1,015	45
Below Algebra II	265	8	427	8	140	8	115	5
Highest Science Course								
Physics	777	24	972	17	410	24	405	18
Chemistry	1,352	42	2,781	49	677	40	1,164	52
Biology or Below	1,095	34	1,908	34	597	35	691	31
Advanced HS Mathematics Coursework								
No	2,023	63	3,820	67	1,101	65	1,387	61
Yes	1,201	37	1,841	33	583	35	873	39
Advanced HS Science Coursework								
No	2,101	65	3,835	68	1,130	67	1,321	58
Yes	1,123	35	1,826	32	554	33	939	42
Average ACT Mathematics and Science Score								
≤ 22	2,511	78	5,022	89	1,317	78	1,820	81
22.5 to 25.5	517	16	536	9	259	15	344	15
≥ 26	196	6	103	2	108	6	96	4
HSGPA								
< 3.30	1,987	62	3,159	56	1,070	64	1,072	47
3.30 to 3.74	771	24	1,553	27	374	22	655	29
≥ 3.75	466	14	949	17	240	14	533	24
Educational Plans								
Bachelor's or Below	2,082	65	3,309	58	1,097	65	1,024	45
Beyond Bachelor's	1,142	35	2,352	42	587	35	1,236	55

Table D2. (continued)

Student Characteristic	Engineering & Technology (N = 3,224)		Medical & Health (N = 5,661)		Computer Science & Mathematics (N = 1,684)		Science (N = 2,260)	
	n	Percent	*n*	Percent	*n*	Percent	*n*	Percent
STEM Interest								
Expressed and Measured	583	23	1,396	29	298	22	679	36
Expressed Only	887	35	1,768	37	502	36	537	29
Measured Only	262	10	388	8	89	6	214	11
No Interest	831	32	1,182	25	493	36	435	23

Note: Gender and STEM interest percentages based on respondents only.

Table D3. Multivariate Results for STEM Persistence at Year 4 by STEM Major Category and Study Sample

STEM Major Category	Modeled Rates			Not Enrolled vs. Persisted in STEM			Left STEM vs. Persisted in STEM		
	Not Enrolled	Left STEM	Persisted in STEM	OR	95% CI		OR	95% CI	
Four-Year Sample									
Engineering & Technology	33	15	53	0.95	0.89	1.01	0.65	0.60	0.69
Medical & Health	36	18	47	1.16	1.09	1.24	0.88	0.82	0.94
Computer Science & Mathematics	32	23	45	1.08	1.00	1.17	1.16	1.07	1.25
Science	31	21	48						
Two-Year Sample									
Engineering & Technology	51	16	33	1.19	1.01	1.40	0.69	0.57	0.84
Medical & Health	55	18	27	1.55	1.34	1.79	0.98	0.83	1.15
Computer Science & Mathematics	52	18	31	1.29	1.07	1.54	0.83	0.67	1.04
Science	44	23	33						

Note: Italics indicate referent group. OR = odds ratio; CI = confidence interval.

Table D4. Multivariate Results for STEM Persisters' Chances of Earning a 3.00 or Higher Cumulative GPA at Year 4 by STEM Major Category and Study Sample

	Four-Year Sample					Two-Year Sample				
STEM Major Category	N	Rate	OR	95% CI		N	Rate	OR	95% CI	
Engineering & Technology	8,714	51	0.67	0.62	0.73	1,009	46	0.97	0.76	1.23
Medical & Health	4,551	73	1.68	1.52	1.87	1,445	48	1.05	0.84	1.30
Computer Science & Mathematics	3,021	60	0.96	0.86	1.08	457	49	1.08	0.82	1.43
Science	11,211	61				697	47			

Note: Italics indicate referent group. OR = odds ratio; CI = confidence interval.

Table D5. Multivariate Results for STEM Degree Completion by STEM Major Category and Study Sample

	Modeled Rates					
STEM Major Category	Year 4	Year 5	Year 6	OR	95% CI	
Bachelor's Degree Completion for Four-Year Sample						
Engineering & Technology	17	29	34	1.04	0.86	1.26
Medical & Health	14	24	28	0.82	0.65	1.03
Computer Science & Mathematics	16	28	32	0.96	0.83	1.11
Science	17	28	33			
Associate's or Bachelor's Degree Completion for Two-Year Sample						
Engineering & Technology	12	16	18	0.97	0.83	1.13
Medical & Health	10	13	15	0.78	0.68	0.89
Computer Science & Mathematics	13	16	19	0.99	0.84	1.18
Science	13	17	19			

Note: Italics indicate referent group. OR = odds ratio; CI = confidence interval.

ACT®

070702170 Rev 1