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Math Counts: Major and Gender Differences in College Mathematics Coursework

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ABSTRACT

Mathematics is an important and hotly contested aspect of U.S. postsecondary education. Its importance for academics and careers and the extent and impact of math achievement disparities are all subject of longstanding debate. Yet there is surprisingly little research into how much and what types of mathematics courses are taken by U.S. undergraduates and the extent of math achievement differentials among students. This article advances the understanding of math course taking by developing course-taking metrics for a nationally representative cohort of bachelor's graduates. Using NCES transcript data to construct consistent measures of mathematics and quantitative course taking, our analysis finds large variability both within and between STEM/non-STEM majors and a large population of non-STEM graduates earning mathematics credits comparable to their peers in STEM fields. Mathematics course taking differs substantially from course taking in other subjects. We also find that often-observed gender differentials are a function of major, not gender, with females in the most mathematics-intensive programs earning as many or more mathematics credits than their male peers.

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Introduction

Mathematics has become both increasingly important to industry and society and a flash point in discussions of higher education policy. Mathematics is often the key metric for assessing education performance (e.g., PISA), a central feature of K–16 STEM education programs, and used across many college majors as a "gatekeeper" course to "weed out" students or constrain advancement (National Research Council, 2013). The outsized role of mathematics courses is typically justified because of an assumed importance in both everyday life and in work where math is viewed as underpinning "such beneficial modern capabilities as Internet search, medical imaging, computer animation, numerical weather predictions, and all types of digital communications" (National Research Council, 2013; National Academy of Sciences, 2013). Mathematics is increasingly required in the workplace to design, develop, and manufacture products and by users of a wide range of products that require mathematical

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computation skills. Concerns about the ability of the educational system to develop a mathematically literate workforce and citizenry have been the focus of a number of studies (National Research Council, 2013) and have led mathematics educators to reassess postsecondary math curricula (Transforming Postsecondary Education–Math, 2018).

At the same time, math coursework has been described as “the single biggest obstacle to retention and completion” among college students (Logue, 2016) and even described by leading mathematics educators as “a burial ground for the aspirations of myriad community college students” (Culinane & Treisman, 2010). Calls for reform of postsecondary mathematics education are widespread, coming from outside and inside of college mathematics departments (Bryk & Treisman, 2010; President’s Council of Advisers on Science and Technology, 2012; Saxe & Braddy, 2015; National Research Council, 2013). Although many agree that postsecondary mathematics education needs improvement, there is disagreement on the nature of the problems and solutions.

Moreover, mathematics is central to other academic disciplines: Engineering, computer science, and social science, among others, incorporate various mathematical fields into their disciplinary methods and practical applications. This has led some to argue for the expansion of course offerings in advanced mathematics and for partnerships between mathematics departments and other disciplines (National Research Council, 2013). There has also been recognition of the need for curricular reform in lower levels of postsecondary mathematics (Saxe & Braddy, 2015).

As mathematics becomes widely used in work and day-to-day decisions, a number of researchers contend that traditional mathematics curricula are ill suited to these needs, arguing that college math requirements should align with the existing workforce demands for mathematical skills. Andrew Hacker (2016) contends that the traditional education route through mathematics in high school and college, starting with algebra and continuing to calculus, is a primary contributor to the problems of dropout and noncompletion at all levels of education. Advanced mathematics underpins much new technology, but as Hacker and others find, topics covered in the standard curriculum do not reflect the mathematical skills needed by most students, workers, and citizens. Factoring polynomial equations, graphing linear and other functional forms, and trigonometric functions are among the topics encountered in college math sequences that are, for most students, removed from any professional or personal application. Michael Handel (2016) has conducted the most extensive analysis of mathematics used in the workplace, finding that although two-thirds of workers use fractions, decimals, and percentages, only 22% use more sophisticated mathematics such as simple algebra (and it is the skilled trades most extensively using this level of mathematics). Overall, most people are not using high-school-level mathematics at work, with 10% of workers using inferential statistics and/or advanced algebra and only 5% using calculus.

Although many agree with Hacker's overall conclusion about the need for an overhaul of "school mathematics" (e.g., Goldstein, 2016), some dispute his assessment of the utility of mathematics as a whole or implications from Handel's work that advanced mathematics is not useful (Devlin, 2017). Others worry about the potential impacts of Hacker's policy suggestions (Karaali, 2016; Lamb, 2016). Other researchers have demonstrated that success in advanced mathematics coursework in the traditional high school sequence correlates with positive outcomes in postsecondary education but, along with Handel (2016), find little evidence of the need for these skills in the labor force where most incumbent workers report math use at elementary levels (Douglas & Attewell, 2017). Based on these findings, the authors suggest that mathematics plays a gatekeeper role for most students.

The debate about the types of mathematics most needed in the college curriculum is based on surprisingly little rigorous investigation of the dimensions of math course taking in U.S. postsecondary education: Currently, how many students are taking which types of mathematics? Are there gaps between groups of students in terms of the number and types of mathematics courses taken? This article provides much-needed nationally representative data regarding who takes mathematics courses in college and the types of courses they are completing. It also addresses an important question about the relationship between gender, program of study, and mathematics coursework. Notably, we find that one constraint on this type of research has been the lack of empirical data and accurate course classifications necessary to conduct foundational research on postsecondary course taking; this research provides important advances in course classification for detailed education analysis. In the following, we discuss research that explores postsecondary math course taking.

Literature review

Research on postsecondary mathematics

Studies of math course taking generally focus on middle school and high school students. Many studies examine how math performance at these levels predicts later education outcomes (Adelman, 2006; Attewell & Domina, 2008; Byun, Irvin, & Bell, 2015; Kim, DesJardins, & McCall, 2015). Other studies observe differential access to advanced math courses in high school according to students' race/ethnicity and socioeconomic status (DeRuy, 2016; Kelly, 2009; Riegle-Crumb & Grodsky, 2010). Gaertner, Kim, DesJardins, and McClarty (2014) found that high school mathematics attainment equivalent to or greater than Algebra II predicted student wages after college, suggesting that completion of these same math courses is also correlated with economic outcomes.

When researchers examine college mathematics course taking, it is usually as a dependent variable to be explained by other factors, particularly high school math curriculum and math performance, as well as demographic characteristics such as student gender and race/ethnicity. DeBoer (1984) found that women took fewer math courses in college than men but also observed that women earned higher average grades in the math courses they did take. Geddes (2015) used the National Longitudinal Survey of Freshmen (NLSF) to examine the role of peer effects in determining students' course taking and major choices, finding that women were less likely than men to take a math course in their freshman year and that female students at schools with a larger proportion of women take significantly fewer math courses overall. Conclusions often drawn from these studies are that there are gender disparities in mathematics course taking and/or achievement.

Other recent studies examine the relationship between students' high school math curricula and their postsecondary mathematics course taking and achievement. These students' high school mathematics curricula were either developed commercially, with the support of the National Science Foundation, or based on the University of Chicago's School Mathematics Project Curriculum. Following these students over eight semesters, these studies found that high school math curriculum type generally did not predict the number or level of difficulty of math courses taken in college (Harwell, Post, Medhanie, Dupuis, & LeBeau, 2013; Post et al., 2010).

While these studies investigate correlates of college math course taking, none explicitly provides a comprehensive inventory of courses taken. Examining the data in each of the studies cited previously, one can ascertain that postsecondary mathematics course taking is generally low. DeBoer's (1984) data indicate an average of 0.9 math courses per student, with 37% taking no math courses at all. Post et al.'s (2010) data indicate that nearly two-thirds of the students in their sample took two or fewer math courses. Geddes's (2015) data on college freshmen show that only half of these students took a college math course in their first year, with an average of one course among those who took any math courses. While these studies provide some insight into questions of postsecondary mathematics course taking, they are far from exhaustive. Moreover, these studies do not explicitly state which types of courses count in their definition of mathematics, potentially biasing course-taking estimates by including only certain types of math courses.

A further problem concerns representativeness. The aforementioned studies focus on specific populations that correspond to research questions with narrower foci. DeBoer's (1984) study examined random samples from three cohorts of students who graduated from one selective liberal arts college. The high school curriculum studies conducted by Post et al. (2010) and Harwell et al. (2013) are based on data from a group of colleges and universities in the upper Midwest and a sample of students who graduated from Minnesota high schools. Geddes (2015) study relies on the NLSF, which is not intended to be nationally representative but instead provides equal-sized samples of students from different racial and ethnic groups attending a group of selective colleges (NLSF, n.d.). In all cases, the researchers note the limitations of their data for generalizing to college students nationally.

Gender and postsecondary mathematics coursework

A long history of research, policy, and media reports discuss gender gaps favoring men in STEM and mathematics in college education and employment. Yet, as with the aforementioned studies, much of the empirical research examining gender differences in mathematics has been focused at the precollege level. Recent studies of high school mathematics achievement suggest that there are no significant gender differences in the rate of advanced mathematics course taking in high school and that gender achievement differences in mathematics standardized tests are minimal (DiPrete & Jennings, 2012; Hyde, Lindberg, Linn, Ellis, & Williams, 2008). Studies that do examine college outcomes note that while women are less likely than men to choose STEM majors in the aggregate, this masks that fact that certain STEM fields (e.g., biology, mathematics) have reached parity, while others (e.g., engineering, computer science) have not (Riegle-Crumb, King, Grodsky, & Muller, 2012; Riegle-Crumb, Kyte, & Morton, 2018; Salzman & Benderly, 2019). The gender differences in major have been attributed to perceptions of gender discrimination and the "chilly climate" for women and some minorities in certain fields (Ganley, George, Cimpian, & Makowski, 2018). Although large differences are observed in initial choice of major, research finds that subsequent attrition from STEM fields in college does not differ by gender (King, 2016). The gender differentials in STEM appear to be specific to some majors and, at the bachelor's level, are evident in advanced mathematics course taking but not in the share of women graduating with mathematics majors or their basic mathematics course taking or achievement. A more in-depth analysis of observed gender differences in advanced college math course taking requires more accurate, detailed, and longitudinal information on college course taking and student characteristics than previously has been available.

We pause here to note the sociological distinction between biological sex and gender that inheres to research in this field. Sex, a biological category, is the traditional variable measured by most surveys in education research. Gender refers to the societal construct of roles and expectations generally linked to individuals' biological sex. Thus while the data presented below measure students' sex, we analyze these differences as related to gender.

National data on postsecondary mathematics

To address the research questions about mathematics course taking as related to its broad use across disciplines as well as in the workplace, data are needed on all postsecondary mathematics courses that are taught in colleges and universities. But the available course-taking data and classification schemas are only partially adequate for this task.

One national association of college mathematics educators, the American Mathematical Society (AMS), collects its own data on math course taking. Every five years, the AMS's Conference Board of the Mathematical Sciences (CBMS) surveys a random sample of mathematics and statistics programs in U.S. colleges (Blair, Kirkman, & Maxwell, 2013). These surveys provide important data on the scope of mathematics course taking and distinctions by level (e.g., precollege, introductory, calculus, and advanced). However, CBMS focuses on mathematics departments and thus collects data that are limited to math courses taught within math departments and are collected at the departmental rather than student level.

The U.S. Department of Education's National Center for Education Statistics (NCES) collects student transcripts as part of its postsecondary longitudinal surveys. These transcript data provide an opportunity for rigorous and nationally representative descriptions of postsecondary mathematics course taking at the student level. Like the CBMS data, NCES's course classifications, and as such their data points, emphasize the kinds of mathematics courses taught in the traditional mathematics sequences. Without significant transformation, this limits the utility of NCES transcript data for comprehensively assessing mathematics course taking in the broadest sense, as relevant to the math and quantitative knowledge used in industry and society and as discussed by most analyses of mathematics education needs.

Even given their limitations, discussions of postsecondary mathematics policy would be greatly enhanced by the use of NCES's transcript data. Unfortunately, very few studies used these data to analyze course taking per se. In one study, Adelman (2004a, 2004b) reviewed three sets of nationally representative postsecondary transcript data, covering the high school graduating cohorts of 1972, 1980, and 1992. His expressed purpose was to demonstrate the utility of these data for education researchers and policy makers; as such, he did not examine any particular subject area in detail. Nonetheless, he makes a number of points regarding postsecondary mathematics. Examining three successive cohorts, his data indicate a general continuity in the proportion of bachelor's degree recipients taking mathematics courses in calculus and statistics and an increase in the proportion taking college algebra (Adelman, 2004a). Among the 1992 cohort, Adelman reports that nearly 80% of bachelor's degree graduates earned fewer than 5 credits in calculus and advanced mathematics. In the same cohort, he found that eight of the 20 college courses with the highest rates of failure and withdrawal were mathematics courses (Adelman, 2004b). Adelman's counts of mathematics course taking do not include many courses that have substantial quantitative content (e.g., biostatistics, quantitative psychology, economic statistics, operations research). Such omissions limit our ability to take a comprehensive inventory of the mathematics content of postsecondary education.

Our analysis takes its cue from Adelman and attempts to map college mathematics course taking using more recent nationally representative student transcript data from NCES's Beginning Postsecondary Students (BPS 04/09) study, examining the sample of undergraduates who started college in 2004 and ultimately earned bachelor's degrees. Using data from the BPS 04/09 survey and transcript studies, we examine four primary research questions:

RQ1: What counts as mathematics course taking in postsecondary education?
RQ2: How does the definition of mathematics course taking affect the distribution of mathematics credits earned by BA/BS completers?
RQ3: Based on those definitions, what does overall mathematics course taking look like among BA/BS completers?
RQ4: What are BA/BS-completing students' outcomes in math courses by course level?
RQ5: Are there evident disparities by gender in course taking at any of these levels?

Data and methods

This analysis of mathematics course taking in postsecondary education follows a descriptive analysis methodology (Loeb et al., 2017). Given the paucity of course-taking research and, as we will explain, the lack of an established mathematic classification schema, this first step of descriptive analysis is needed before attempts at causal analyses. In other words, the foundational research on mathematics postsecondary education requires developing a substantively coherent classification schema and descriptive analysis of the extent and variation in mathematics course taking.

The classification of mathematics course taking is a significant undertaking because, as we detail in the following, it differs from most other course subjects by being taught outside of a single discipline and by being integrated into other disciplinary fields. That is, to understand mathematics education broadly, other than just courses taught within mathematics departments, we need to identify courses that provide mathematics content across the campus. We first discuss the constraints in the existing data and classification schemas and then describe our approach to developing a mathematics course classification schema.

NCES postsecondary transcript data

The NCES longitudinal surveys of college students' course taking are supplemented by data collected from those students' college transcripts. NCES first began to classify college programs of study in the 1980s with the creation of the Classification of Instructional Programs (CIP), a six-digit coding system consisting of two digits indicating the general category (e.g., biological science, social science) and four additional digits indicating subcategory and specific subject field (e.g., microbiology, criminology). This taxonomy facilitates the classification of credentials offered by postsecondary institutions and earned by students.

The CIP system was used to code college transcript data from one of the earliest national longitudinal education surveys, the National Longitudinal Survey of the High School class of 1972 (Malitz, 1981). Analysis of this initial round of transcript coding (Adelman, 1990) indicated that around 40% of the course records in that transcript file were classified inaccurately due to both the limitations of the CIP system and poor quality control procedures. NCES recoded those data with the aim of creating a system that reflected the subject matter of courses being taught in U.S. colleges to create the College Course Map (CCM). Specific efforts were made to collapse redundant classification categories and to disaggregate those that were too general (Adelman, 1990).

The CCM thus relies on CIP categories, but its descriptions facilitate comparison with available descriptions of individual courses, rather than with instructional programs (Adelman, 1990; Bryan & Simone, 2012). The researchers responsible for creating and revising the CCM consulted subject-matter experts —especially with respect to mathematics and core sciences—to better interpret transcript data and to identify substantively meaningful distinctions between different general course areas and specific course content. In the coding process, coders also utilized college course catalogs and information about students' fields of study to reconcile ambiguous course titles. The original CCM included fewer six-digit codes than the CIP.

The CCM has evolved to reflect changes in the subject matter taught in colleges, undergoing revisions in 1993, 2003, and 2012 (Adelman, 1995, 2003, 2004a). The most recent CCM revision, finished in 2012, after the 2010 CIP revision, was based on transcript analysis of both the Beginning Postsecondary Students Longitudinal Study (BPS) 04/09 and Baccalaureate and Beyond Longitudinal Study 2009 (Bryan & Simone, 2012).

CCM course codes generally reflect the disciplinary home of a course (e.g., biology course) taught in biology department receives a general, two-digit code for biology, while the detailed four-digit classification reflects course content. Nonetheless, some courses do not have clear disciplinary or content identities. In the documentation for the original CCM, Adelman (1990) offered the example of the course entitled "Human Growth and Development," which was observed in biology, psychology, anthropology, and education. NCES coders encountering such a course would use information in the college's course catalog and information about the students' major field of study to identify the proper code for the course, which may or may not correspond to the course title. A course entitled "Statistics," for example, could be offered in any number of departments. Coding staff would use the college's course catalog and information about students' programs of study to ascertain whether this course would be coded 13.0603 (education statistics and research methods), 14.9995 (engineering mathematics, engineering statistics), or 27.0501 (statistics, general). This two-point classification schema—using both the course listing and the student's major—could result in the same course being coded differently for two students with different majors. Specifically, one student's credits could be counted as math credits, while another student's credits for the same course might be classified as nonmath.

We examine NCES's Beginning Postsecondary Students (BPS) survey of students who began college in 2003–2004. To ensure that our analysis examined an internally consistent population, we focus on those students who completed a bachelor's degree within six years, and who had substantially complete transcript records (NCES, 2011).

Operationalizing mathematics

There is no single definition of "mathematics." Most definitions include reference to symbolic manipulation and its application to questions of quantity, change, and relation,[1] but these characteristics do not provide enough specificity to guide the classification of courses. Constraining the definition to courses taught in mathematics departments or by mathematics faculty might be useful for examining disciplinary course taking, as is the case with the data collected by CBMS. However, for most education and workforce analyses, a more useful goal would be to identify the extent of skills involving formal mathematics, statistics, and/or more broadly conceived quantitative skills often referred to as "quantitative reasoning" (National Research Council, 2013).

Classification systems for courses and disciplines, including the CIP and CCM, often combine "pure" mathematics and statistics. Many academic disciplines outside of mathematics use statistics as a research tool. Statistics is often a methodology requirement in natural and social sciences, as well as in business, engineering, and some health programs. Further, most colleges have a mathematics general education requirement that may be fulfilled by a course in "quantitative reasoning," primarily for liberal arts and humanities students. These courses may fall outside standard definitions of both mathematics and statistics. Thus, accounting for undergraduate students' math coursework in transcript data requires deciding how broad a definition to adopt and locating all of the applicable entries in the course taxonomy.

Our math course-taking and credit-earning variables reflect a broad conception of mathematics, including courses that provide core mathematics education as taught in mathematics departments, applied courses such as statistics taught in other disciplines, and courses such as quantitative reasoning. Our classification thus includes all postsecondary courses generally considered to provide math education, including all disciplinary math courses, statistics courses, precalculus, and other selected quantitative courses (see Table A1 and Appendix A for a complete list and additional discussion). This classification method allows researchers to modify the definition and provide a substantively coherent and consistent analysis (e.g., by including or excluding all statistics courses or not including quantitative reasoning, etc.).

Defining course taking and credit earning

Two important issues emerged in the process of coding and cleaning the NCES transcript files: removing duplicate course records and removing courses in which students did not earn credits.

Unidentified transfer courses

NCES requests transcripts from all colleges attended by surveyed students. Thus, one problem of duplicated courses occurs when students transfer from one institution to another and the course is counted twice, on both the sending and receiving institutions. Although there is a BPS-Postsecondary Education Transcript Survey (PETS) flag to indicate a duplicate course, a large number of duplicate courses were not flagged as such.

Unidentified repeat courses

A more significant issue with credit counting concerned repeated courses for which a student received credit more than once. When a student repeats a course after earning a failing grade, course credits accrue for only the one course with a passing grade. However, many programs require students to earn a minimum grade, such as a C or a B, to continue in course sequences. In these cases, a student who received a passing grade that accrued credit on the transcript would repeat the course to receive a grade that enabled them to satisfy requirements for their major or to continue in a course sequence. When a student repeated a course that accrued credit in both instances, both were included in BPS aggregated (derived variable) credit counts.

Although the BPS-PETS does contain a flag for repeated courses, our analysis found a substantial number of repeated classes that were not flagged as such.[2] In our assessment, we found a substantial number of credits earned in courses subsequently retaken by the students were double-counted. This may be a more substantial problem for math courses than other subjects because math courses serve as prerequisites in many programs. Thus, a weakness in math would necessitate retaking a math course for progression in nonmath and math majors alike, whereas low performance in other courses would be less likely to result in large numbers of repeated courses. To assess overall math course taking among BA/BS earners, we count each unique course only once; students who, for example, took calculus I twice—earning a D on the first attempt and a B-minus on the second—would only show the credit equivalent of one calculus I course in our estimates. Without this correction, the BPS derived variables double-count repeat courses, showing a poorly performing student who took calculus I twice as earning twice the calculus credits of a stronger student who took the course once and received an A.[3]

Accounting for these two problems, we used the courses data file to calculate detailed counts of all math course credits, including precalculus courses and statistics courses taught outside math departments. We then used the course title information to identify repeated courses and recorded credit for only one course. This method results in a calculation of "Comprehensive Net Credit Count" (CNCC). This variable is a credit count using a broad definition of math, to include all courses that fit the more comprehensive definition of mathematics, and did not count repeated courses even if credits were earned for both attempts.

The impact of these changes is shown in our analysis of the net differences between using the BPS-PETS-derived variables to account for math course taking and our CNCC approach and revised definition of mathematics. Then, using our CNCC method, we examine differences in math credit earning among students in the BPS who completed a bachelor's degree within six years of having started college at any two- or four-year institution. For additional discussion of our methodology, especially as it concerns students' major fields of study and degree completion status, see Appendix B.

Finally, as explained previously, we note that our analysis of gender differences relies on the BPS survey variable measuring respondents' reported sex.

Findings

Counting credits and definitions of mathematics

Our Comprehensive Net Course Count (CNCC) classification relies on a more inclusive definition of "mathematics" than the NCES measure and eliminates duplicate course counts, resulting in a large change in aggregate math course-taking counts. Comparing our measure with the mathematics course-taking-derived variables provided in BPS transcript data, we find an average increase of 1.5 math credits among bachelor's degree graduates. Combining the derived variables provided by NCES yields an estimate of

9.1 earned math credits on average, while the CNCC method estimates 10.6 credits, a net average increase of 16%.[4]

The changed specifications do not have differential impacts by gender. We see a similar net increase in the number of reported math credits earned by men (+1.6) and women (+1.4). In terms of major, the CNCC specification shows the largest increases in average math credits earned among students majoring in computer science (+2.2), social sciences (2.0), and business (+3.2). The smallest net changes were observed among students with degrees earned in mathematics and statistics (+0.2), engineering (+0.2), and education (no net change). The additional courses included in our definition of mathematics generally came from business and social science fields, explaining the pattern of changes by student major. Throughout the rest of the article, we use the CNCC specification of mathematics courses.

Investigating overall mathematics credit earning

Assessing mathematics credit earning by student major, we find the expected large difference between STEM and non-STEM BA/BS graduates, as reflected in the group means in Table 1 and the density distribution (Figure 1). In the distribution, non-STEM graduates cluster below 10 math credits, while STEM graduates peak at 10 credits followed by a gradual decline and a second lower peak at 21 credits. However, the figure also shows: (a) a considerable share of STEM graduates with relatively low levels of earned math credits, (b) a substantial overlap of the two

Table 1. Math credits earned by counting method, gender, and major, BA/BS graduates.

	BPS-derived		CNCC			
	Mean	*SD*	Mean	*SD*	Mean Δ	*N* (Weighted)
TOTAL	9.1	8.1	10.6	8.1	+1.5	1,047,888
Gender						
Female	8.1	7.1	9.5	7.3	+1.4	603,233
Male	10.6	9.0	12.1	8.9	+1.6	444,655
STEM	16.6	12.0	17.6	11.7	+1.1	212,369
Agriculture/Natural Resources	9.1	5.6	10.9	6.7	+1.8	20,054
Architecture	11.1	8.7	12.7	8.9	+1.6	10,819
Computer Science	15.6	9.5	17.8	9.3	+2.2	27,253
Engineering	22.2	6.5	22.4	6.8	+0.2	58,070
Life Sciences	9.1	4.9	10.3	4.9	+1.2	64,955
Math and Statistics	48.3	11.7	48.5	10.9	+0.2	12,195
Physical Sciences	16.9	10.2	17.8	9.9	+0.9	19,023
Non-STEM	7.2	5.2	8.9	5.7	+1.6	835,519
Business	8.9	4.9	12.1	5.4	+3.2	212,343
Communications	5.2	3.6	5.8	3.8	+0.6	69,251
Education	9.3	8.0	9.3	7.8	+0.0	91,360
Health	6.9	4.0	8.1	4.3	+1.2	71,906
Humanities	5.8	4.6	6.5	4.8	+0.7	161,307
Social Sciences	6.2	4.5	8.2	5.0	+2.0	194,798
Other/Unknown	7.7	4.9	8.5	5.1	+0.8	80,909

Source: Beginning Postsecondary Students 04/09, transcript file.

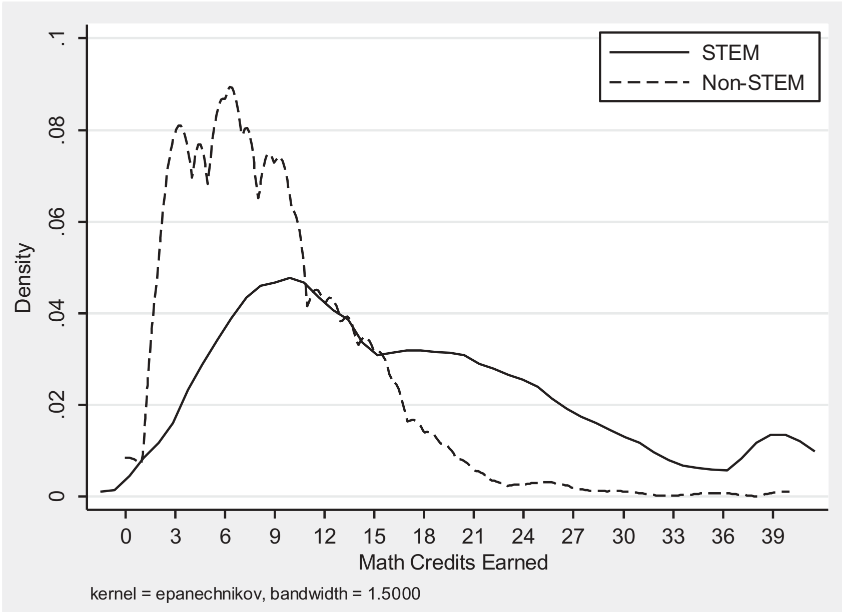

Figure 1. Math credits earned by major group among BA graduates. Kernel density. *Note*. Credit earning variable top-coded at 40 credits. *Source*: Beginning Postsecondary Students 04/09, transcript file.

distributions between 9 and 21 math credits, and (c) a considerable proportion of non-STEM graduates with math credits at or above the mean for STEM graduates (about 18 credits).

Credit share analysis

To account for the vastly different population sizes of different majors, Table 2 assesses the relative numbers of total math credits earned by major, weighting average credits earned by population size, which we call a "credit share." This analysis constrains the population to those who complete a BA/BS so that comparisons are between groups with similar periods of course taking. To the extent that enrolled noncompleters have different course-taking behaviors, the full distribution of all course taking will differ from the course-taking distribution of BA/BS earners.

Although STEM graduates take almost twice as many math credits on average as their non-STEM counterparts, there are four times as many non-STEM graduates; accordingly, non-STEM students account for approximately two-thirds (67%) of all math credits earned by BA/BS graduates. Looking at a more detailed classification, we observe that mathematics and statistics graduates comprise about 1% of the BA/BS graduate population and account for just over 5% of the math credits earned by BA/BS graduates.

Table 2. Mathematics credits earned by math intensity and student major, BA/BS graduates.

	Mean math credits earned	Population (weighted)	Percentage of all graduates	Total credits earned (millions)	Percentage of all math credits
Major group					
non-STEM	8.9	835,519	80%	7.4	67%
STEM	17.6	212,369	20%	3.7	33%
Detailed major					
Business	12.1	212,064	20%	2.6	23%
Humanities	6.1	139,642	13%	0.9	8%
Social Sciences	8.2	187,935	18%	1.5	14%
Other Non-STEM	8	295,878	28%	2.4	21%
STEM, non-Math	15.7	200,174	19%	3.1	28%
Math & Statistics	48.5	12,195	1%	0.6	5%
Major group by math intensity level					
< 9 credits	4.8	478,993	46%	2.3	21%
STEM	5.7	46,793	4%	0.3	2%
non-STEM	4.7	432,200	41%	2.0	18%
9–14.9 credits	10.8	331,914	32%	3.6	32%
STEM	11.3	55,448	5%	0.6	6%
non-STEM	10.7	276,466	26%	3.0	27%
15–20.9 credits	16.9	141,083	13%	2.4	21%
STEM	17.6	40,743	4%	0.7	6%
non-STEM	16.6	100,340	10%	1.7	15%
21 + credits	29.8	95,898	9%	2.9	26%
STEM*	30.8	69,385	7%	2.1	19%
non-STEM	27.3	26,513	3%	0.8	6%
Totals	*10.6*	*1,047,888*	*100%*	*11.1*	*100%*

*All Math majors are found in this group.
Source: Beginning Postsecondary Students 04/09, transcript file.

Non-math STEM graduates take fewer math credits on average than math majors, and their share of credit earning (19% of BA/BS graduates and 28% of math credits) is only somewhat higher than business majors (20% of BA/BS graduates and 23% of math credits).

Next, we consider total share of math credits earned by students' level of college math intensity (operationalized as total math credits earned). As previously with major categories, we calculate credit shares as the mean number of math credits in an intensity category multiplied by the population in that category. The lowest credit-earning group (those who earned fewer than 9 math credits each) makes up 45% of the BA/BS graduate population and earns a fifth of all math credits earned by BA/BS graduates. The next group (earning between 9 and 15 math credits) constitutes 32% of the population and earns 32% of all math credits. Combining these two groups, we observe that bachelor's degree graduates who earn fewer than 15 math credits account for just over half of all earned math credits. The high-intensity math course taking population, those earning 15 or more credits comprising 47% of BA/BS graduates, account for nearly half of all math credits earned. As noted previously, since this analysis excludes noncompleters and courses for which no credits were earned, this does not estimate the overall math course enrollments and their distribution.

Course success and credit earning by mathematics course type

The BPS transcript data further allow researchers to identify mathematics courses by type. As such, we first consider course outcomes by broad type or level using courses, rather than students, as the unit of analysis. This is similar to analysis of outcomes conducted by Adelman (2004a). We divide course outcomes into four categories: failure/withdrawal, passing in a pass/fail course, passing with a grade lower than a C, and passing with a grade of C or better. We chose "C" as a threshold because it is typically the minimum grade needed to advance through course sequences. As is the case throughout the article, we restrict our analysis to the subsample of students who earned bachelor's degrees.

Among BA/BS completers, precollege level courses are more likely to end with a failure or withdrawal (13%) than any other type of mathematics course (Figure 2). Pre-college-level mathematics courses also have the highest rate of passing in courses using pass/fail grades (7%), perhaps reflecting that more of these courses are offered as pass/fail, because precollege mathematics courses often do not count toward a student's GPA.

Courses in advanced mathematics and college-level mathematics have equal rates failure or withdrawal (10% each) and similar "C or better" rates (77% to 78%). Notably, among mathematics course types, courses in statistics and applied mathematics have the lowest failure/withdrawal rate (7%) and the highest proportion of grade C or better (84%).

We provide four additional course groupings for comparison. Three are other STEM fields: biological sciences, physical sciences, and engineering; and one is another subject typically required of all college students: English. Across non-mathematics STEM fields, which are generally considered to be as rigorous as

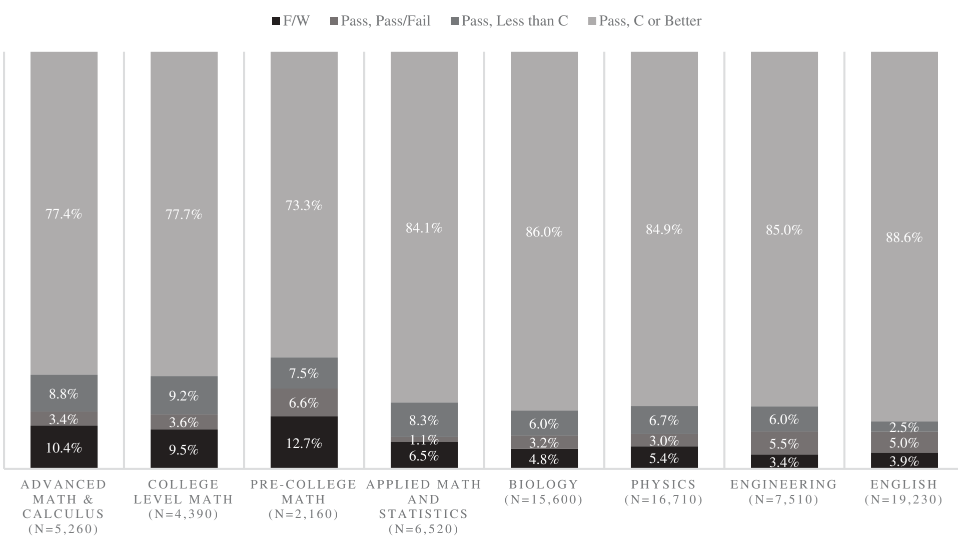

Figure 2. Mathematics and other course outcomes by type, BA/BS graduates.

mathematics, we observe course failure/withdrawal rates of between 3% and 5%, and "C or better" rates of about 85%. English courses, which are similarly required of most or all college students, have a 4% failure/withdrawal rate and an 89% C or better rate. In sum, we observe that mathematics courses have generally poorer outcomes than other courses among BA-/BS-earning students. Notably, statistics and applied mathematics courses are more similar to these other nonmath courses. In supplemental Table C1, we compare these course outcomes (among BA/BS earners) to course outcomes among all postsecondary students in the BPS-PETS data. We find similar patterns distinguishing traditional mathematics courses from applied math and statistics courses and the nonmathematics course categories analyzed previously. Notably, among all postsecondary students, course success rates are substantially lower in college-level mathematics and precollege mathematics.

Credit earning by mathematics course type and student characteristics

We analyze postsecondary mathematics credit earning by the types of math courses taken and student traits in Table 3. Specifically, we present the proportion of students who earned any credit in a given course type and the average number of credits earned in that type, if any. We analyze results separately by gender and by broad major classification, STEM and non-STEM.

As expected, almost all students who earn bachelor's degrees earn at least some mathematics credits (98%). Overall mathematics credit-earning gaps are observed between men (12.3 credits) and women (9.7 credits), and STEM (17.7 credits) and non-STEM graduates (9.0 credits). A quarter of BA/BS graduates earned credits in precollege math and, as might be expected, a larger proportion of non-STEM graduates earned credits in this category.

About two-thirds of BA-/BS-completing students earn any credits in college level math (64%). Men and women who earned any college level math credits

Table 3. Mathematics credits earning by BA/BS graduates by course type and student traits (weighted N = 1,047,888).

	Precollege math		College-level math		Statistics/applied math		Advanced math and calculus		All mathematics levels	
	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned
Gender										
Male	27.0	4.6	65.6	4.8	73.1	5.5	53.4	7.8	98.8	12.3
Female	30.2	4.6	65.6	4.8	67.8	4.6	35.0	6.6	99.0	9.7
Major Area										
STEM	16.5	4.9	62.9	5.7	78.2	6.2	83.9	10.3	99.5	17.7
Non-STEM	32.0	4.5	66.3	4.6	67.9	4.6	32.4	5.1	98.8	9.0
Total	28.9	4.6	65.6	4.8	70.0	5.0	42.8	7.2	98.9	10.8

Source: Beginning Postsecondary Students 04/09, transcript file.

earned the same average number of math credits in this category, while STEM graduates earned more such credits (5.7) than did non-STEM graduates (4.8).

A similarly large proportion of BA/BS graduates earned at least some credits in statistics and applied math (69%). There was a noticeable gap in ever earning credits in this category between men and women (72% vs. 67%) and between STEM and non-STEM majors (78% vs. 67%). Among those who earned any such credits, we also observe gender and major area differences in the numbers of credits earned.

The largest differences across genders and major areas were observed in advanced mathematics and calculus. Only 41% of BA-/BS-completing students earn advanced math or calculus credits. As might be expected, a much larger share of STEM students (82%) earn advanced math or calculus credits than non-STEM students (31%). The gender gap in the incidence of earning any advanced math and calculus credits (34% among women, compared to 51% among men) is much larger than the gap observed in other math course types. Among those students who earned credits in advanced math and calculus, men (7.8) earned 1.2 more credits on average than women (6.6).

Although gender disparities in mathematics have long been discussed (DeBoer, 1984; Geddes, 2015), the differences we observe in math credits by major suggest that further analysis is necessary. Since course requirements vary by major, and there are large differences in advanced math credit earning in some majors that have fewer women (e.g., engineering), we want to differentiate between direct or first-order gender differences in math course credits and indirect or second-order math credit differences that reflect difference in credit earning as a function of major. Perhaps to a greater extent than many other fields, math course credit earning reflects college requirements rather than individual student discretion. Precollege math course taking is often a college requirement for those below certain math proficiency levels; college-level math is often a general education requirement; and most advanced math courses are required in a select group of majors such as engineering or mathematics. Thus, our next step in the analysis considers the interactions between discipline and gender.[5]

Advanced math (e.g., topology, functional analysis, vector analysis) and calculus are required in most STEM majors but not in most non-STEM majors. The first set of regression models presented in Table 4 examines the effect of gender, STEM major, and their interaction. Social scientists are split on whether to apply weights when conducting predictive analysis (Solon, Haider, & Wooldridge, 2015), and one approach is to compare both the weighted and unweighted regression models, which will identify interactions that appear sensitive to weighting effects.

Overall, women take about 1.2 fewer advanced math credits than men do in the group of BA/BS graduates who have earned such credits (see Table 3). In the regression model shown in Table 4, which is for all BA/BS graduates

Table 4. Advanced mathematics credit earning among BA/BS graduates. OLS and WLS regression.

	Gender only		Gender, major		Gender, major, interactions	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
Gender (ref. Male)						
Female	−1.75 (0.14)***	−1.81 (0.22)***	−0.72 (.12)**	−0.68 (0.18)***	−0.59 (0.13)***	−0.55 (0.12)***
Major (ref. non-STEM field)						
STEM field	–	–	6.91 (.15)***	6.79 (0.32)***	7.18 (0.20)***	7.06 (0.46)***
Interaction Terms						
Female*STEM	–	–	–	–	−0.59 (0.29)	−0.63 (0.69)
Model R^2	.029	.032	.319	.316	.320	.471
N (rounded, unweighted)	5,320					
N (weighted)	1,047,888					

*p < .05; **p < .01; ***p < .001.
Source: Beginning Postsecondary Students 04/09, transcript file.

(including those who have not earned advanced math credits), the gender difference is 1.8 credits in the weighted sample and 1.75 in the unweighted sample. When we control for major, the gender difference in advanced math credits earned is reduced by more than half, to .68 credits (weighted) or .72 credits (unweighted). The STEM major effect is just under 7 credits (6.9 unweighted; 6.8, weighted). The interaction of gender and STEM shows no significant difference, though the gender differential is still about 0.6 credits lower for women. In this model, the advanced math credit difference between STEM and non-STEM majors is large (7 credits), and the interaction of STEM major and gender appears to account for most of the gender difference.

But "STEM" is a highly aggregated classification, as shown earlier (Table 1), with large differences in overall math credit earning. We disaggregate STEM into two distinct subgroups, based on the average number of math credits earned by students in those fields. The first—biological sciences, computer science, and other STEM (BCO) majors—constitutes 58% of STEM majors and earns on average 4.8 advanced math credits. The second—physical sciences, engineering, and mathematics (PEM) majors—comprises 42% of STEM majors and earns an average of 13.7 advanced math credits, nearly three times the average credits of the BCO group. To examine the effect of major on advanced math course taking among STEM graduates, we specify a regression model of gender, STEM-BCO, and STEM-PEM, with non-STEM as the reference category and the gender interaction for each group. This analysis is presented in Table 5. As expected from the prior analysis of STEM/non-STEM, advanced math course taking is related to STEM major, but there is large and significant difference between the STEM-BCO and STEM-PEM groups, with the former group accounting for an increase of about 3 advanced math credits, while the STEM-PEM group accounts for over 11 advanced math credits. We observe no

Table 5. Advanced mathematics credit earning among BA/BS graduates, STEM subgroups. OLS and WLS regression.

	Gender only		Gender, major		Gender, major, interactions	
	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
Gender (ref. Male)						
Female	−1.75 (0.14)***	−1.81 (0.22)***	−0.36 (.11)**	−0.33 (0.15)*	−0.59 (0.12)***	−0.55 (0.12)***
Major (ref. non-STEM field)						
B/C/O	–	–	3.19 (.16)***	3.17 (0.26)***	2.98 (0.23)***	2.81 (0.38)***
P/E/M	–	–	11.85 (.18)***	11.99 (0.42)***	11.08 (0.22)***	11.39 (0.54)***
Interaction Terms						
Female*B/C/O	–	–	–	–	0.35 (0.32)	0.68 (0.50)
Female*P/E/M	–	–	–	–	2.31 (0.39)***	1.95 (1.20)
Model R^2	.029	.032	.464	.468	.467	.471
N (rounded, unweighted)	5,320					
N (weighted)	1,047,888					

Note. Major categories: B/C/O = Biological Sciences, Computer Science, and Other STEM; P/E/M = Physical Sciences, Engineering, and Mathematics.
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.
Source: Beginning Postsecondary Students 04/09, transcript file.

interaction effect between STEM-BCO and gender. However, in the STEM-PEM group, the STEM major group with the highest levels of advanced math credits, we find a rather large gender differential but in the opposite direction from the gender effect in the prior models. Said another way, women in the STEM major group with higher levels of advanced math credit earning, STEM-PEM, earn about 2 more advanced math credits than men in the same programs. Though the weighted analysis does not reach statistical significance, the positive coefficient suggests that, at a minimum, women are not at a disadvantage in advanced math credit earning.

Conclusion

Limitations

Our chosen subsample—BA/BS completers—limits our study to perhaps the best-case scenario of postsecondary education. However, comparative analysis by demographic subgroups requires populations with comparable end points to control for variations that reflect different education trajectories such as earning an associate's degree, dropping out, and/or taking extended periods to degree completion. That is, to avoid confounding institution type or noncompletion with course-taking outcomes, we needed to limit the sample to those who had completed their course of study and thus had the potential to earn comparable numbers of mathematics credits. The method of credit counting developed here can be used in future research on other postsecondary populations, including two-year college students and students who do not complete degrees. Removing duplicate and failed courses also limits the scope of our analysis to unique math courses for which credits are earned. This corresponds to our particular research questions about credit earning. The revised course classification developed here could be applied to studies of course failures and repetitions, which are worthy directions for future research.

Discussion

Mathematics is widely acknowledged as necessary to a well-rounded college education and as an integral part of the modern economy. Owing to a relative paucity of empirical evidence, recent notable studies and books (National Research Council, 2013; National Academy of Sciences, 2010) have expressed concerns about the extent of mathematics education that college students receive. One complication of any detailed assessment is that there is no accepted standard of course content that comprises “mathematics”; most discussions about necessary mathematics education center around a minimum of quantitative reasoning and symbolic manipulation. But no more specific definition has been consistently or coherently operationalized. Additionally, the technical means for examining postsecondary mathematics education have been insufficient. NCES collects student transcripts along with its nationally representative postsecondary surveys, but the data were not classified to facilitate comprehensive analysis of mathematics course taking.

To address these issues, we revised NCES’s mathematics course classification to constitute a measure of mathematics course taking that broadly reflects quantitative education in U.S. colleges. We first classified all mathematics or quantitative courses and eliminated duplications, then distinguished among mathematics course types. Our revised classification identified a nearly 30% increase in average mathematics course credits among a cohort of BA/BS graduates.

Our subsequent analysis identified several notable aspects of postsecondary mathematics education among college graduates. First, mathematics credit earning is substantial among non-STEM BA/BS graduates. In fact, the population of non-STEM graduates who earn as many or more mathematics credits as the median STEM graduate is approximately equal in size to the STEM graduate population with similar levels of credit earning. While the non-STEM graduating cohort is about four times the size of the STEM graduating cohort, it is nonetheless notable that a large share of non-STEM graduates earn mathematics course credits at levels comparable to their peers in STEM fields. This finding strongly suggests, contrary to prevailing wisdom, that students across a wide range of majors achieve moderate or greater levels of mathematics education.

Our findings concerning completion and failure rates suggest that more attention may need to be paid to traditional mathematics courses in college.

Although some may conclude from our analyses that mathematics courses are inherently more difficult than other subjects, there is little evidence to support such claims. Higher pass rates are observed in other similarly rigorous STEM courses. Another contention is that mathematics courses serve a larger segment of the college population, thus creating downward selectivity bias. However, we find that pass rates are also markedly higher in English courses, which serve a similarly broad portion of college students. Finally, courses in statistics and applied mathematics also diverge from traditional mathematics course outcomes. Since many applied courses are taught outside of mathematics departments, this finding may suggest that departmental mathematics faculty have a distinctly stringent approach to grading. Another possibility is that students better engage mathematical content when it is related to their field of study (Parker, Traver, & Cornick, 2018). Indeed, researchers are beginning study alternative approaches to delivering mathematics content in college, focusing on applied quantitative literacy and statistics (Logue, Watanabe-Rose, & Douglas, 2016; Yamada & Bryk, 2016) Thus, pedagogy, course content, and grading standards should each be considered as partial explanations of these outcomes.

A related finding concerns course taking in statistics and applied mathematics. We observe that a large majority (nearly 70%) of BA/BS graduates earn credits in this category, suggesting that colleges and students have long recognized the importance of these courses and that Hacker's (2016) critique may have overlooked the extent to which college graduates are, in fact, earning mathematics credits that are relevant for their employment and daily life. Indeed, more recent data from the American Mathematical Society show that statistics and applied mathematics are the fastest-growing segment of postsecondary mathematics degrees (Blair, Kirkman, & Maxwell, 2018).

Another often discussed aspect of mathematics education is gender disparities that favor men. Our analyses show a statistically significant substantial gender disparity in math credits earned, a nearly 2-credit deficit among women graduates. However, we find that this disparity is concentrated in advanced mathematics and calculus course credits; other types of mathematics credit earning show little or no gender disparity.

Further, we observed that advanced mathematics and calculus course taking appears to be a function of disciplinary requirements, with high levels of such course taking in physical sciences, engineering, and mathematics majors. Our analysis of the relationship between major and mathematics credits earned showed that students in these three majors earn approximately 11 more credits in advanced mathematics than other groups. In two of these three majors, engineering and physical sciences, there is a large gender disparity, with men comprising about two-thirds of those majors. While mathematics majors have a much closer gender balance, it is a very small major category and thus accounts for a small fraction of this group's average mathematics credits earned.

We analyzed this interaction of major and gender and found that what appears to be a gender deficit in overall math course taking is, instead, a reflection of the intensity of advanced mathematics course credits required in a specific group of majors that are predominately composed of male graduates. In fact, the analysis indicates that not only is there no gender deficit in math credits when accounting for major, but women in high-intensity majors appear to earn more math credits than their male counterparts. It is plausible that mathematics courses, as "gate-keepers," are responsible for this second-order effect—functioning as a barrier to women's entry into these majors; but this is not indicated by our data. There is a large population of high math-credit-earning women in the overall graduate population, and women have achieved near parity in mathematics majors for nearly half a century. This analysis suggests that the mathematics course require-ments, per se, are unlikely to be the key barrier to women entering engineering and physical sciences. In terms of education policy, this research suggests that gender disparities in mathematics-intensive fields are not the result of presumed gender differences in mathematical competence but likely due to other factors in those fields and/or departments.

In summary, mathematics education is more widespread than previously documented: The lack of comprehensive and consistently constructed metrics significantly underestimates the extent and breadth of mathematics credits earned by college graduates. The classification developed here now allows for such analyses and the ability to modify the classification in a consistent manner to examine different characteristics of mathematics course taking. It is this improvement in the classification schema and course-accounting procedures that allows the first comprehensive assessment of postsecondary mathematics education. Although mathematics course taking is low for some groups, it is nonetheless far more extensive and intensive than often assumed. Moreover, the long-presumed gender disparities in mathematics education appear to be a function of gender disparities in some majors, not a deficit in mathematics education or ability.

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Notes

1 One definition reads as follows: "The science of quantitative relations and spatial forms in the real world. Being inseparably connected with the needs of technology and natural science, the accumulation of quantitative relations and spatial forms studied in mathematics is continuously expanding, so this general definition of mathematics becomes ever richer in content" (The European Mathematical Society, 2012). The National Science Foundation (2015) supplies a definition of mathematics that is combined with computer science: "… employs logical reasoning with the aid of symbols and is concerned with the development of methods of operation using such symbols or with the application of such methods to automated information systems."
2 NCES staff confirmed that the flag was not comprehensive because it only appears when transcripts explicitly note a repeated class.
3 This is an example of how analytic purposes determine methodological decisions: An analysis of course-taking frequency might wish to count all courses taken regardless of outcome and would thus construct a different measure.
4 These are net differences that include courses excluded in the NCES coding schema and resolve duplicate course counts, thus lowering the course-taking count with the NCES-coded classification; thus, the extent of course reclassification and counts are more extensive than apparent in the averages.
5 In Table C2, we also consider course taking and credit earning by broad race/ethnicity categories. These analyses suggest that students from underrepresented minority groups take more precollege mathematics courses and fewer advanced mathematics and calculus courses than their White and Asian counterparts. We were not able to include race/ethnicity in the final regression models because of small cell sizes for this sample.
6 This last decision rule connects with our larger effort to assess the STEM content of earned bachelor's degrees. Depending on their particular aims, other researchers could certainly decide on different decision rules.
7 For complete details on the transcript request process, see section 4.1.5 of the BPS methodology report (National Center for Education Statistics, 2011).

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Appendix A: Defining math courses

The two-digit general CIP code for mathematics and statistics is 27, so most math courses listed in the table are found under this general code. The BPS-derived mathematics variables also include certain courses in basic skills (32), engineering (14), education (13), biology (26), social science (45), and business (52). Nonetheless, this list did not account for all college mathematics courses, either by a strictly departmental criterion (courses taught in mathematics departments or by mathematics instructors), or a broader definition of mathematics, including courses that would be taught outside of mathematics departments. Further, some courses were on more than one derived variable list—specifically overlapping between *qesta* (statistics) and either *qemat* (college math) or *qeclc* (advanced math and calculus)—which precluded simply adding the four variables together.

To develop a mathematics course metric, we adopt a broad definition of mathematics, which includes statistics courses taught in nonmath departments and other selected quantitative courses. Our derived mathematics variables include all those classified as mathematics by NCES, and the following additional courses, presented in Table A2.

Among the courses added, precalculus (27.9996) stands out because it is listed under the CIP two-digit general code for mathematics. In communication with NCES staff, we determined that this was a coding error, albeit a substantial one. A total of 1,200 courses for which students earned credits were coded as precalculus. The other courses on this list reflect our purpose of including all courses with substantial mathematics content.

Table A1. CCM codes of NCES-defined mathematics and statistics courses.

Precollege mathematics (qepma)	College-level mathematics (qemat)	Advanced mathematics (qeclc)	Statistics (qesta)
27.0195	27.0101	27.0103	27.0501[a]
27.0196	27.0102	27.0105	27.0502[a]
27.0197	27.0104	27.0304	27.0503[a]
27.0198	27.0199	27.0306	27.0598[b]
27.9990	27.0301	27.0598	27.0599[a]
32.0104	27.0303	27.9994	27.9999[a]
	27.0305	27.9995	13.0603
	27.0399	14.9995	14.9995[b]
	27.0501		26.1101
	27.0502		26.1102
	27.0503		42.2708
	27.0599		45.0603
	27.9988		45.9998
	27.9989		52.1302
	27.9991		
	27.9992		
	27.9993		
	27.9997		
	27.9998		
	27.9999		

Source: Authors' tabulation of the BPS 04/09 Transcript Study codebook (National Center for Education Statistics, n.d.).
Note. Titles of CCM course codes can be found in Bryan and Simone (2012).
[a]Overlap between *qesta* and *qemat*.
[b]Overlap between *qesta* and *qeclc*.

Table A2. Additional CCM course codes included in the Comprehensive Net Course Count (CNCC) of postsecondary mathematics.

CCM course code	Category title
24.0195	Quantitative Reasoning, Mathematical Ideas, and/or Applied Problem Solving
38.0102	Logic
27.9996	Analytic Geometry, Elementary Functions, and/or Precalculus
52.1301	Management Science
52.1304	Actuarial Science
52.1398	Administrative Science and/or Administrative Systems
52.1399	Management Sciences and Quantitative Methods, Other

Source: Authors' tabulation of data from the 2010 College Course Map (Bryan & Simone, 2012).

Appendix B: Student majors and degree completion

Classifying major field of study

To assess students' math course taking by major field of study, we needed to classify students' majors. In the BPS data, major field of study can come from two sources: institutional administrative data (transcripts) and student report (surveys). Conflict between the administrative data and the interview data were nontrivial as were missing data fields. Thus, we created a single major field of study variable by following three general steps:

(1) For students whose transcript- and interview-reported majors aligned, we kept the transcript value (i.e., there was no conflict).
(2) For those who were missing one or the other data point, we substituted the nonmissing value.
(3) For those whose interview- and transcript-reported majors did not align, we selected the major that accorded with their number of earned STEM credits.[6] We developed the following decision rules to determine how to resolve interview and transcript reports.

We calculated the 25th percentile of earned STEM credits by major, separately for interview and transcript report variables.

If students had both a STEM and non-STEM reported major, but fell above the 25th percentile for earned STEM credits for the STEM major, they were coded with that major.

If students had two different reported STEM majors, but fell below the 25th percentile for one of them, they were coded with the other major.

For students with two different reported STEM majors whose STEM credits fell below either majors' 25th percentile for earned STEM credits, we manually browsed their course history to make decisions based on the timing of courses taken and the totality of their course taking history. Only about 0.5% of the sample (representing 1.5% of the weighted cases) was classified using this procedure.

Defining degree earners in transcript data

Our analysis was restricted to bachelor's degree completers to facilitate comparison among a population with otherwise comparable numbers of courses taken. As with major, degree completion can be based on student or administrative reports. For course-taking analysis, it is also necessary to work only with complete student transcripts, which account for an entire degree worth of completed courses. The BPS-PETS data provide normalized credit estimates in which an earned bachelor's degree would correspond to between 120 and 160 credits. However, we found a substantial number of cases in which the survey and/or transcript data reported a student to have a BA/BS degree, but the reported transcript credits were far lower than the normal range of bachelor's degree requirements. In other cases, the transcript and interview report variables for degree completion did not agree. An interview report of a degree not reflected in the transcript could be a technical discrepancy, for example, of an unpaid fee but completion of all formal requirements; a transcript-reported degree but not a self-reported degree we infer to be a coding or reporting error.

NCES requested transcripts from all colleges attended by students.[7] The records appear to be entirely or nearly complete from the final college attended but less complete from the previous colleges of transfer students. About 60% of the sample attended more than one college. We believe this is the source of discrepancy between transcript-reported bachelor's degrees and the numbers of course credits reported. Discussion with NCES staff suggested no other obvious causes for the discrepancies.

Given these limitations, we define bachelor's degree completers as those students with either transcript- or self-reported degrees and with courses totaling to 105 or more earned credits.

Appendix C: Supplemental tables

Table C1. Mathematics and other course outcomes by type, all postsecondary students and BA/BS graduates.

	All postsecondary students				BA/BS graduates			
	F/W	Pass, Pass/Fail	Pass, less than C	Pass, C or better	F/W	Pass, Pass/Fail	Pass, less than C	Pass, C or better
Advanced Math & Calculus (*N* = 7,790)	16.5%	3.0%	9.9%	70.6%	10.4%	3.4%	8.8%	77.4%
College Level Math (*N* = 13,500)	22.0%	3.3%	9.6%	65.2%	9.5%	3.6%	9.2%	77.7%
Pre-College Math (*N* = 11,450)	29.4%	6.7%	7.1%	56.8%	12.7%	6.6%	7.5%	73.3%
Applied Math and Statistics (*N* = 10,220)	13.4%	1.1%	9.1%	76.4%	6.5%	1.1%	8.3%	84.1%
Biology (*N* = 29,080)	11.5%	2.5%	7.2%	78.9%	4.8%	3.2%	6.0%	86.0%
Physics (*N* = 25,690)	10.9%	2.7%	8.0%	78.5%	5.4%	3.0%	6.7%	84.9%
Engineering (*N* = 9,770)	6.2%	4.9%	7.1%	81.8%	3.4%	5.5%	6.0%	85.0%
English (*N* = 43,200)	14.0%	4.5%	4.3%	77.1%	3.9%	5.0%	2.5%	88.6%

Source: Beginning Postsecondary Students 04/09, transcript file.

Table C2. Mathematics credits earning by BA/BS graduates by course type and student race/ethnicity (weighted *N* = 1,047,888).

	Precollege math		College-level math		Statistics/applied math		Advanced math and calculus		All mathematics levels	
	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned	% earned any credits	Average # of credits earned
Race										
White or Asian	26.5	4.4	63.6	4.7	70.2	5.0	44.5	7.2	98.8	10.7
Underrepresented minority	40.5	5.2	73.5	5.2	68.5	4.9	34.3	7.1	99.5	11.2
Other race categories	24.9	4.5	72.4	5.3	71.0	4.8	47.0	7.7	99.7	11.7
Total	28.9	4.6	65.6	4.8	70.0	5.0	42.8	7.2	98.9	10.8

Note. The "Underrepresented Minority" race category includes students who self-identified as Black/African American, Hispanic, Native American or Alaska Native, and/or Hawaiian/Pacific Islander in the BPS 04/09 survey. The "Other" race categories includes students who self-identified as two or more races, or other race in the BPS 04/09 survey.
Source: Beginning Postsecondary Students 04/09, transcript file.