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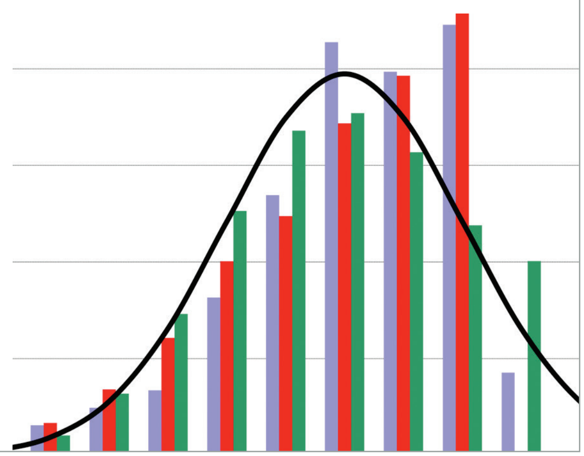

Trends in Achievement Gaps in First-Year College Courses for Racial/Ethnic, Income, and Gender Subgroups: A 12-Year Study

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Trends in Achievement Gaps in First-Year College Courses for Racial/Ethnic, Income, and Gender Subgroups: A 12-Year Study

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Abstract

Prior research has demonstrated gaps in the academic success of college student subgroups defined by race/ethnicity, income, and gender. We studied trends over time in the success of students in these subgroups in particular first-year college courses: English Composition I, College Algebra, social science courses, and Biology. The study is based on course grade data for 1998 through 2009 from over 330,000 students enrolled in 101 colleges. Success in a course was defined as obtaining either a B or higher grade or a C or higher grade in the courses. Achievement gaps were defined as differences in probabilities of success among student subgroups, after controlling for high school grade point average (GPA) and ACT® College Readiness Assessment scores.

Female students outperformed male students in all of the first-year credit-bearing college courses used in the study, with the largest differences being observed in English Composition I and College Algebra. From 1998 to 2009, however, the gender achievement gap narrowed in English Composition I and Biology. Students from low-income families were less likely to succeed in all four courses, and income gaps in English Composition I and social science courses increased over time. Gaps for African American students and Hispanic students were observed in English Composition I, social science courses, and Biology, but not in College Algebra. Racial/ethnic achievement gaps expanded over the twelve years in the social science courses, but the gap between African Americans students and White students in Biology narrowed over time.

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Trends in Achievement Gaps in First-Year College Courses for Racial/Ethnic, Income, and Gender Subgroups: A 12-Year Study

Introduction

Studies have shown that students from different socio-demographic subgroups perform at different levels in college, even when they entered college with the same level of high school achievement (Carpenter, Ramirez, & Severn, 2006; Bailey & Dynarski, 2011; Robinson & Lubienski, 2011). Researchers typically study college achievement gaps by examining subgroup differences in college outcomes (such as course grades, grade point average (GPA), or retention) after accounting for differences in pre-college academic and nonacademic variables (for example, high school GPA or college admission test scores). College achievement gaps are often called *differential prediction*. Differential prediction refers to the situation where predictions of college outcomes based on test scores differ significantly among student subgroups (Young, 2001; Culpepper & Davenport, 2009). Radunzel and Noble (2013) assessed differential effect on racial/ethnic, family income, and gender groups of using ACT® College Readiness Assessment Composite Score, ACT College Readiness Benchmarks, and high school grade point average for predicting long-term college success. Sanchez (2013) examined the differential effects of using ACT test scores and high school GPA to predict first-year college GPA among racial/ethnic, gender, and income subgroups. Both studies concluded that minority and low-income students at both two- and four-year institutions "are not disadvantaged by using ACT Composite score or the Benchmark scores" to predict first-year GPA (Sanchez, 2013) or longer-term success in college (Radunzel & Noble, 2013). In this study, we define college achievement gaps as subgroup differences (for instance, male versus female or low-income versus middle/high income students) in the probabilities of success in first-year credit-bearing college courses, after controlling for ACT test scores, high school GPA, and other student demographic variables. We define success as earning grades of B or higher or C or higher in first-year credit-bearing courses – English Composition I, College Algebra, social science courses, and Biology. To assess the trend of college achievement gaps since the late 1990s, we examine the magnitude and direction of achievement gaps across twelve first-year student cohorts, from 1998 to 2009.

It is important to understand and address college achievement gaps because "the continued existence of substantial minority-majority educational gaps is prohibitively costly, not only for minorities, but for the nation as a whole" (Miller, 1995, p. 4). An Achievement Gap Report (Klein, 2009) estimated that, if educational achievement gaps were closed, the economy of the United States, as a whole, could have seen gains in the Gross Domestic Product (GDP) of 2008 between $310 billion and $2.3 trillion, depending on the subgroup achievement gap.

Academic achievement gaps have been documented at various points in the educational pipeline for racial/ethnic (Carpenter et al., 2006; Hemphill & Vanneman, 2011; Miller, 1995; Vanneman, Hamilton, Baldwin Anderson, & Rahman, 2009), income (ACT, 2010; Bailey & Dynarski, 2011; Evans & Rosenbaum, 2008; Reardon, 2011), and gender subgroups (Cook, 2006; Dee, 2006; Glenn & Van Wert, 2010; Robinson & Lubienski, 2011). Below, we summarize prior studies on K-12 and college achievement gaps for each class of students (race/ethnicity, income, and gender).

Racial/Ethnic Achievement Gap

In comparison to White students, K-12 academic achievement gaps for racial/ethnic minorities, composed of African American, Hispanic, and Native American students, have decreased significantly over time. However, significant gaps continue to exist, and more recently these gaps seem to have stagnated (Miller, 1995). A review of several studies found that racial/ethnic gaps exist in K-12 grade levels, but they are especially large in higher education (Miller, 1995; Reardon, 2011; Lee, 2002). Reardon (2011) examined nineteen studies with nationally representative samples using mathematics and reading test scores as K-12 outcomes. The study found that the achievement gap between African American students and White students in reading decreased for cohorts born between 1940 and 1970 at which point it remained relatively constant, while the achievement gap in mathematics decreased over the same period. Lee (2002) suggested that achievement gaps between African American and White students, and between Hispanic and White students, narrowed throughout the 1970s and 1980s, and increased in the 1990s.

The National Assessment of Educational Progress (NAEP) examined the achievement gap between Hispanic and White students, and, separately, between African American and White students. Results showed that the achievement gap between Hispanic and White students did not change from 1990 to 2009 for mathematics or reading for students in grades 4 and 8 (Hemphill & Vanneman, 2011). Meanwhile, over the same period, the gap between African American and White students either remained stable or narrowed depending on the grade level of the students: for grade 4 students, the gap in mathematics and reading narrowed; for grade 8 students, the gap in mathematics narrowed and remained stable in reading compared with prior assessments (Vanneman et al., 2009). In science, the African American and Hispanic achievement gaps narrowed from 2009 to 2011 for grade 8 students (National Center for Education Statistics, 2012).

College achievement gaps have also been documented for African American and Hispanic students relative to White students (Culpepper & Davenport, 2009; Noble, 2003; Young, 2001; Bridgeman, McCamley-Jenkins, & Ervin, 2000; Miller, 1995; Young, 1994). Relative to White students, African American and Hispanic students earned college grades lower than would have been predicted by their high school grades and test scores. Another recent study noted racial/ethnic gaps in college enrollment, retention, and students' chances of earning a first-year GPA of 3.0 or higher (ACT, 2010). Not surprisingly, the gaps were somewhat reduced among the subset of students who were college-ready in all four subject areas. These findings are consistent with the college achievement gap definition used in this study; that is, certain student subgroups are less likely to achieve college success, even after adjusting for high school grades and test scores.

Income Achievement Gap

Several studies on the academic achievement gaps of students from low-income families have been conducted (Evans & Rosenbaum, 2008; ACT, 2010; Reardon, 2011; Bailey & Dynarski, 2011). Reardon (2011) found that income-based K-12 achievement gaps in mathematics and reading have been growing over the last 50 years and are approximately twice as large as the African American (vs. Whites) achievement gap (based on achievement differences between the 90^{th} and 10^{th} percentiles of family income). Reardon also concluded that the income-based achievement gap was large when students entered kindergarten and there did not appear to be any discernible trend as children advanced in education. Based on U.S. Census data and other sources, Bailey & Dynarski (2011) found that over the last 70 years the income-based gap in college entry, persistence, and graduation has increased.

Another recent study found that income-based gaps in college enrollment, retention, and students' chances of earning a first-year GPA of 3.0 or higher are smaller among the subset of students who were college-ready in all four subject areas (ACT, 2010). Similarly, after controlling for pre-college achievement, students from low-income families were less likely to be prepared for college, less likely to enroll in college, and less likely to persist to college graduation, compared to students from middle/high-income families (Radunzel & Noble, 2012a).

Gender Achievement Gap

Historically, females have been a subgroup of concern in education (Robinson & Lubienski, 2011), and researchers continue to be concerned with their representation and performance in Science, Technology, Engineering, and Mathematics (STEM) fields (Mikyake, Kost-Smith, Finkelstein, Pollock, Cohen, & Ito, 2010; Robelen, 2012). However, more recently, educators have become increasingly concerned with the performance and representation of males in education (Glenn & Van Wert, 2010; Robinson & Lubienski, 2011; Cook, 2006). Males are more likely to repeat a grade than females (Dee, 2006), less likely to graduate from high school and enroll in college (Riordan, 1999; Sommers, 2000), and are less likely to persist to college graduation (Glenn & Van Wert, 2010).

Studies have shown that although boys and girls start kindergarten with approximately equivalent test scores, within a few years, girls outscore boys in reading, while boys score better in mathematics and science (Dee, 2006; Robinson & Lubienski, 2011). These achievement gaps continue to grow throughout primary and secondary school (Dee, 2006). In mathematics, the gender differences in achievement are most pronounced at the higher end of the performance scale (Stoet & Geary, 2012; Robinson & Lubienski, 2011). In reading the gaps are larger at the lower levels of performance metrics (Robinson & Lubienski, 2011). However, Mullis, Martin, and Foy (2008, as cited in Robinson & Lubienski, 2011) show that the gender achievement gaps in mathematics are small and vary over time and place. Thus, we caution on the interpretation of gender achievement gaps since the direction of the gap may depend upon "which grade and subject one examines, which students one considers, and which outcome variables are used" (Robinson & Lubienski, 2011, p. 297).

Prior studies point to an underprediction of college grades for female students relative to male students. This suggests the existence of a gender achievement gap in postsecondary institutions, with females outperforming males. The gap appears to be less pronounced at selective universities (Young, 2001; Bridgeman & Wendler, 1991; Young, 1994).

Research Questions

Most studies have focused on achievement gaps that form before or during K-12 education (c.f. Robinson & Lubienski, 2011). In studies of gaps in college achievement among socio-demographic subgroups (including differential prediction research), attention has been given to the magnitudes of the achievement gaps, with less emphasis placed on whether the sizes of the gaps are increasing or decreasing over time. Previous studies have also centered on broad measures of academic success (e.g., first-year GPA, retention, degree completion) instead of success in particular first-year courses. An observed effect for an overall measure of success (e.g., first-year overall GPA) might not pertain to success in specific areas (e.g., grades in first-year courses). Moreover, because students do not all enroll in the same courses, first-year GPA doesn't measure the same constructs for all students. To minimize the effect of course selection on overall grades (Young, 2001), this study focused on subgroup achievement gaps in specific college courses that are commonly taken by students during the first year of college, with implications on subsequent academic opportunities. College placement decisions often rely in part on the students' academic performance during their first-year of college (Noble, 1991; Noble, Crouse, & Hanson, 1996). Students who underachieve in a particular course may be denied admission into specialized fields of study. Correct or incorrect course placement may have consequences for the students, racial/ethnic subgroup, gender subgroups, and the institution (Cheng & Noble, 1993; Noble et al., 1996). The purpose of this study, therefore, is to address the following research questions:

1. Do achievement gaps exist in first-year college courses by racial/ethnic minority (African American, Hispanic, and other[1]), income, and gender subgroups?
2. Did the sizes of the college achievement gaps change between 1998 and 2009?

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[1] To improve the sample size and power to detect significant differences, the "other" race/ethnicity category included American Indian/Alaska Natives, multiracial, and other students who did not identify as African American, Asian, Hispanic, or White.

Methodology

Data and Sample

We used first-year college course grade data for ACT-tested students. Most of the first-year credit-bearing college course data were collected through institutions' participation in ACT® Course Placement or ACT® Prediction Research Services (ACT, 2006), whereby institutions provide course grade data and receive institution-specific research reports relating ACT scores to course grades. Data were also obtained through other partnerships between ACT and postsecondary institutions.

Study variables. Besides ACT test scores, the pre-college data included self-reported high school course grades and demographic variables collected from students when they registered to take the ACT test. The Course Grade Information Section (CGIS) of the ACT registration collects information on 23 high school courses that form the basis of college preparatory curriculum or are frequently required for admission into college. These courses are grouped into four categories: English, mathematics, social studies, and natural science. The self-reported course work and grades collected are generally accurate relative to the actual information provided on student transcripts (Zhang & Sanchez, 2013; Mattern & Shaw, 2009; Sawyer, Laing, & Houston, 1988). Noble (1991) suggests that, although self-reported student grades are slightly inflated compared to actual grades reported on transcripts, the self-reported grades are sufficiently accurate for use in student subgroup studies. We calculated high school grade point average (on the usual 0.0 to 4.0 scale) from the 23 high school course grades that students reported when they registered for the ACT. Students also provided data on their race/ethnicity, family income, and gender when they registered for the ACT [2]. We used five racial/ethnic subgroups for analysis: African American, Asian, Hispanic, White, and Other. We considered two levels of family income level: less than or equal to $30,000 and more than $30,000. The split at $30,000 income level made it plausible to compare our findings with those of other studies on college achievement gaps (ACT, 2010; Bailey & Dynarski, 2011).

The first-year courses[3] used in this study include English Composition I (the typical English Composition course taken by freshmen), College Algebra, Biology, and social science courses (including American History, Economics, Other History, Political Science, Psychology, and Sociology). Hereafter, we refer to English Composition I as English Composition. We chose these courses because they represent distinct content areas and are commonly taken by students during the first year of college. All courses were typical first-year credit-bearing courses that were neither developmental nor honors.

The ACT test includes subject tests in four areas: English, Mathematics, Reading, and Science. For analysis purposes, each college course grade was paired with the most closely aligned ACT subject test[4]: English Composition with the ACT English test, College Algebra with the ACT Mathematics test, social science courses with the ACT Reading test, and Biology with the ACT Science test.

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[2] Family income level data were collected using ten levels: 0 – Less than $18,000; 1 – About $18,000 to $24,000; 2 – About $24,000 to $30,000; 3 – About $30,000 to $36,000; 4 – About $36,000 to $42,000; 5 – About $42,000 to $50,000; 6 – About $50,000 to $60,000; 7 – About $60,000 to $80,000; 8 – About $80,000 to $100,000; 9 – More than $100,000. Students were classified as low-income if they reported a family income of $30,000 or less (categories 0, 1, or 2).

[3] Because not all college courses under the general course title (e.g., English Composition, College Algebra, and Biology) have the same content and scope across institutions, it would be more accurate to label these as "course types." This is especially true for the social science courses, which include a mixture of general course titles. For simplicity, we refer to the course groups as "courses."

[4] ACT subject test scores range from 1 to 36.

We defined cohort year as a student's high school graduation year, which is usually the year of first college enrollment.[5] We assembled the data for students who graduated from high school between 1998 and 2009 for which ACT test data could be matched to college course grade data. Then, we removed duplicate records so that there remained at most one record for each combination of student and course.[6]

Institution samples. The data consisted of combinations of institution/course/ cohort of at least 30 students with full data (course grade, ACT scores, high school grade point average (HSGPA), race/ethnicity, income, and gender). To ensure continuity in institutions across time and reduce confounding institutional effects and time trends, we required that each institution/course combination have at least five cohorts represented[7]. The data included 101 institutions (68% 4-year and 32% 2-year institutions; 89% public and 11% private institutions). Table 1 gives the percentage of institutions by course, broken down by institution type, control, and admissions selectivity policy. The number of institutions per course ranged from 39 for Biology to 79 for English Composition. Almost all (96%) of the 2-year institutions had an open admissions policy, while three-quarters (75%) of the 4-year institutions had a traditional (55%) or more selective (20%) admissions policy.

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[5] Year of first enrollment was known for 96% of the sample, and was equal to high school graduation year in 96% of those cases.
[6] For students with multiple social science courses, we chose one record at random.
[7] Of the total 101 institutions: 10 institutions had 5 cohorts (10%), 5 had 6 cohorts (5%), 12 had 7 cohorts (12%), 17 had 8 cohorts (17%), 7 had 9 cohorts (7%), 8 had 10 cohorts (8%), 19 had 11 cohorts (19%), and 23 institutions had 12 cohort years (23%).

Table 1

Proportions of Colleges with Different Characteristics, by College Course

	College course			
Characteristic	English Composition	College Algebra	Social Science	Biology
Type	(N=79)	(N=52)	(N=58)	(N=39)
2-year	0.35	0.31	0.29	0.36
4-year	0.65	0.69	0.61	0.64
Control				
Public	0.91	0.96	0.93	0.90
Private	0.09	0.04	0.07	0.10
Admission policy[8]				
Highly selective	0.01	0.00	0.02	0.03
Selective	0.11	0.12	0.10	0.13
Traditional	0.37	0.46	0.40	0.36
Liberal	0.03	0.04	0.03	0.05
Open	0.48	0.38	0.45	0.44

Student samples. Overall sample sizes (number of unique students across the courses) varied across cohorts from a maximum of 39,091 students for 2003 to a minimum of 13,081 students for 2009 (See Table 2). English Composition had the largest enrollment of students (N=231,344), followed by the social science courses (N=199,973). Meanwhile, Biology had the least number of students (N=59,809). In general, the two beginning years (1998 and 1999) and the ending year (2009) of the twelve-year span contained the smallest number of students.

[8] The admissions policies of the institutions in this study were self-reported and classified according to the high school class ranks of their accepted freshmen. The majority of freshmen at highly selective schools are in the top 10%; selective, in the top 25%; traditional, in the top 50%; and liberal, in the top 75% of their high school class. Institutions with open admissions policies accept all high school graduates to limit of capacity.

Table 2

Student Sample Sizes, by College Courses and Cohort Year

		College course			
Cohort year	Overall	English Composition	College Algebra	Social Science	Biology
1998	15,436	11,420	6,439	12,240	4,296
1999	15,869	11,729	5,415	13,257	4,429
2000	36,638	28,245	10,245	19,148	5,999
2001	35,804	25,350	11,488	21,400	6,067
2002	37,463	26,072	12,037	21,445	6,334
2003	39,091	28,228	11,241	19,411	6,129
2004	34,837	24,203	10,276	19,138	6,767
2005	32,953	20,280	11,360	19,171	6,266
2006	28,211	17,904	9,316	17,909	5,496
2007	23,003	13,658	7,356	14,336	3,810
2008	26,141	16,361	9,037	15,639	3,148
2009	13,081	7,894	3,353	6,879	1,068
Total	338,527	231,344	107,563	199,973	59,809

Table 3 contains frequency distributions for race/ethnicity, income level, gender, and institution type for each course. To assess the representativeness of our sample relative to first-time enrolled college freshmen, we compared each sample data to the population of ACT-tested high school graduates of 2009 who enrolled in college in fall of 2009. Across courses, our data comprised of, mostly, White students (0.74-0.77) and females (0.57-0.58). Most of the students (0.77-0.80) enrolled in a 4-year college. Additionally, our sample data included slightly smaller proportions of African-American and Hispanic students (Table 3), compared to other racial/ethnic subgroups; and smaller proportions of students from low-income families (Table 3), compared to students from middle/high income families.

Table 3

Proportions of Students with Different Demographic Characteristics, by College Course

Demographic characteristic	College course: English Composition	College Algebra	Social Science	Biology	Population[9]
Race/Ethnicity					
Asian	0.02	0.02	0.03	0.02	0.05
African Americans	0.09	0.09	0.08	0.09	0.12
Hispanic	0.03	0.03	0.04	0.03	0.08
Other	0.08	0.09	0.09	0.09	0.03
White	0.77	0.76	0.74	0.75	0.71
Income Level					
Low	0.24	0.23	0.25	0.24	0.27
Middle/High	0.76	0.77	0.75	0.76	0.73
Gender					
Female	0.58	0.57	0.58	0.58	0.56
Male	0.42	0.43	0.43	0.42	0.44
Institution Type					
2-year	0.23	0.23	0.20	0.23	0.26
4-year	0.77	0.77	0.80	0.77	0.74

Note: Percentages may not add to 100% due to rounding.

The pre-college academic achievement variables (ACT scores and HSGPA) varied across the subgroups and courses. Differences in pre-college academic achievement reflect gaps that developed and existed before college. It is important to distinguish these gaps from the college achievement gaps (subgroup differences in college achievement, after accounting for pre-college achievement) that are the focus of this study. Table 4 contains average ACT scores for each course and subgroup (for each

[9] The batch of ACT-tested high school graduates of 2009 who enrolled in college in fall 2009 was used as the population. College enrollment data was obtained through ACT's Class Profile Service and the National Student Clearinghouse.

course, the aligned ACT subject area score is used). Each sample and subgroup can be compared to the population of 2009 ACT-tested college enrolled freshmen.

Table 4

Mean ACT Subject Scores, by Student Subgroup and College Course

	College course			
Subgroup	English Composition	College Algebra	Social Science	Biology
Race/ethnicity				
Asian	20.9	22.2	21.2	21.3
African American	18.0	17.3	18.2	18.2
Hispanic	20.0	20.0	20.8	20.3
Other	20.2	19.4	21.0	20.4
White	21.8	21.1	22.3	21.6
Income level				
Low	19.8	19.2	20.4	20.0
Middle/high	21.7	21.0	22.2	21.6
Gender				
Female	21.6	20.0	21.9	20.7
Male	20.8	21.3	21.6	21.8
Total sample	21.0	20.5	22.1	21.2
Population	21.7	21.9	22.4	21.7

For each course, the total sample had slightly smaller mean ACT scores (in the related subject area) than the population of ACT-tested college freshmen of 2009. College Algebra – with mean ACT Mathematics score of 20.5 – had the largest difference, compared to 21.9 for the population. As expected, we found differences among subgroups: racial/ethnic minority (African American, Hispanic, and other race/ethnicity) and low-income students earned lower mean ACT scores than White (or Asian) students and middle/high income students, respectively. Across subgroups and courses, African American students had the lowest mean ACT scores. Females had higher ACT English and ACT Reading mean scores than males, while males scored higher, on average, on the ACT Mathematics and Science tests.

Defining Course Success

In this study, we defined success as obtaining a B or higher grade (or a C or higher grade) in the given first-year credit-bearing college course, resulting in a dichotomous definition of achievement. Students who withdrew from the course were coded as unsuccessful. We chose this dichotomous definition of success for both conceptual and technical reasons, including:

1) Students strive for higher grades (Covington, 1999; Covington & Wiedenhaupt, 1997), and generally view grades of B or higher as successful. Traditionally, grades of C or higher have been regarded as satisfactory or better.
2) Students who earn first-year grades of B or higher, on average, are much more likely to complete a postsecondary degree. Among students in a 4-year college who earned a first-year GPA of at least 3.00 (B or higher grades), 64% earned a Bachelor's degree within six years; compared to 27% for students whose first-year GPA was less than 3.00. Similarly, among students enrolled in a 2-year college who earned a first-year GPA of at least 3.00, 51% earned an Associate's or Bachelor's degree (in a separate institution) within six years; versus 19% for students whose first-year GPA was less than 3.00.[10]
3) Course grades below C are not assigned with much frequency. In our sample, the following percentage of students earned below C: 12% in English

[10] The degree completion percentages were obtained from the data set described in a published study, Radunzel and Noble (2012b).

> Composition, 23% in College Algebra, 19% in the social science courses, and 20% in Biology. Arguably, the B criterion better reflects the grading practices college faculty use to discriminate student performance.

Hereafter, the B or higher outcome is referred to as the B criterion and the C or higher outcome is referred to as the C criterion.

Statistical Modeling

To answer the research questions posed, we used multilevel logistic regression to model the binary B criterion, or C criterion, on pre-college academic achievements and student demographics. Zhang and Sanchez (2013) found that test scores increased accuracy of prediction for each student demographic subgroup over high school GPA (HSGPA). Noble (1991) and ACT (2013) showed that a modest improvement in prediction accuracy when college grades prediction models are based jointly on ACT scores and high school grades rather than on either ACT scores or HSGPA, alone. We fitted separate models for each course. In each model, predictors included HSGPA, the student's ACT score in the relevant subject area, race/ethnicity, income level (low vs. middle/high), gender (male vs. female), and cohort year. We used the following reference subgroups: White students (for race/ethnicity with White coded as "0"), middle/high income students (for income level with middle/high-income coded as "0" and low-income coded as "1"), and female students (for gender with female coded as "0 and male coded as "1"),

To facilitate interpretation of regression coefficients, we standardized HSGPA and ACT scores to a mean of 0 and standard deviation of 1. The study coded cohort year as 0 (1998) through 11 (2009). We used interactions between each subgroup indicator and cohort year to test for trends in college achievement gaps over time. For example, a positive estimate for the coefficient of the male gender-by-cohort year interaction would indicate that the female-male achievement difference decreased from 1998 through 2009; it could also mean that the direction of the differences changed over time. In addition to the full models that included the interaction terms, we also fit main-effects only models meant to estimate conditional probabilities of course success. Further details on the model are given in Appendix A.

Interpreting logistic regression estimates. Estimates of logistic regression coefficients represent changes in log-odds of success, per unit change in the predictor of interest. To facilitate interpretation, it is common to transform the coefficients to odds ratios and changes in probabilities. For each subgroup, course, and criterion, there are three probabilities of primary interest:

1) Overall conditional success probabilities. These probabilities are derived from the main-effects only models. The conditional probabilities for each subgroup can be derived from the model intercept, the coefficient for the subgroup of interest, and by averaging over the other variables in the model. For example, to obtain the conditional probability for males, we assume mean ACT score and mean HSGPA (values of 0), middle cohort year (2003-2004), equal subgroup membership in low vs. middle/high income, and equal subgroup membership in each racial/ethnic classification.
2) The *base year* conditional success probabilities (and corresponding odds ratios). Because of the cohort and interaction terms, the success probabilities and odds ratios (comparing two subgroups) vary across the twelve years.

Because the first cohort year (1998) is coded as 0, the value of all interaction terms is 0 for the base year, and the base year probability estimates are derived from the model's main effects estimates. Moreover, the base year achievement gap for each subgroup (relative to the reference subgroup) is tested by the logistic regression coefficient corresponding to the subgroup. The conditional probabilities for each subgroup can be derived by averaging over the other variables in the model.

3) Predicted probabilities over time for cases of significant trends in college achievement gaps. The interaction terms test whether subgroup performance changed over the twelve-year span, relative to the reference subgroup. For selected cases where trends in achievement gaps are statistically significant, we present graphs of the conditional probabilities over time.

In this study, we report the findings on achievement gaps in terms of conditional probabilities of success, comparable to Young (2001). We use trends to discern progress over time.

Effects of nesting. Before fitting the final models, we examined the effects of nesting (students within institutions) by fitting unconditional (no predictor variables) multilevel logistic regression models for binary outcomes. This made it possible to compute the intra-class correlation coefficient (ICC) – a measure of the degree of clustering in the dataset.[11] Using formula (9) of Rodriguez and Elo (2003, p. 37), we computed ICC for the binary outcomes. Table 5 displays the estimated ICC values, by course and grade criterion. The ICC values ranged from 0.04 (for the B criterion in

[11] The ICC can be interpreted as the correlation between any two observations in the same group, or as the proportion of variance explained by clustering (Rodriguez & Elo, 2003).

English Composition) to 0.12 (for the C criterion in Biology). The results suggest that the institution the students attended have an influence on success in the four courses studied. The ICC for the C criterion in English more than doubled the ICC for the B criterion. The ICC values were about the same for the B and C criteria in College Algebra, Social Science, and Biology.

Table 5

Intra-class Correlations, by College Courses and Grade Criterion

	B Criterion	C Criterion
College course	ICC	ICC
English Composition	0.04	0.10
College Algebra	0.07	0.08
Social Science	0.07	0.05
Biology	0.11	0.12

We fitted a multilevel random intercept model, with institution-specific intercepts to account for the nesting of students within institutions. In all courses, a pseudo-likelihood ratio test[12] of whether it was necessary to model variance across institutions resulted in a significant p-value, validating the use of multilevel analysis. The fitted-model did not include random slopes, so we assumed that the effects of each predictor, and interaction between predictors, are the same across institutions. We qualified an effect as significant if the p-value was less than or equal to 0.05.

Results

Course Success Rates

Table 6 shows the proportion of successful students, by course, institution type, and cohort year. We found that overall students succeeded more in English Composition

[12] For instance, in English Composition at the B criterion, Test of Covariance Parameters: DF=1, Chi-Square Statistics = 6,286.70, P-Value < 0.0001.

(0.69 for the B criterion, 0.87 for the C criterion) than in either College Algebra, Biology, or the social science courses – they succeeded least in College Algebra (0.51 and 0.74) and Biology (0.52 and 0.78). Generally, across years, success varied considerably by institution type. For example, relatively fewer students in 2-year institutions met the B criterion in English Composition (0.62 versus 0.72) and relatively more students in 2-year institutions met the B criterion in Biology (0.59 versus 0.49).

Table 6

Proportion Successful, by College Course, Institution Type, and Cohort

Variable	College course							
	English Composition		College Algebra		Social Science		Biology	
	B	*C*	*B*	*C*	*B*	*C*	*B*	*C*
Inst. Type								
2-year	0.62	0.80	0.50	0.74	0.54	0.76	0.59	0.83
4-year	0.72	0.89	0.51	0.74	0.56	0.81	0.49	0.76
Cohort								
1998	0.69	0.86	0.48	0.72	0.55	0.79	0.54	0.81
1999	0.67	0.86	0.50	0.74	0.56	0.80	0.56	0.81
2000	0.69	0.88	0.51	0.75	0.57	0.81	0.56	0.81
2001	0.72	0.89	0.53	0.77	0.56	0.81	0.54	0.80
2002	0.71	0.89	0.52	0.77	0.56	0.80	0.52	0.79
2003	0.69	0.88	0.53	0.77	0.55	0.80	0.51	0.80
2004	0.69	0.87	0.53	0.76	0.57	0.80	0.50	0.77
2005	0.69	0.86	0.50	0.73	0.57	0.80	0.49	0.76
2006	0.68	0.85	0.48	0.71	0.55	0.78	0.49	0.75
2007	0.66	0.84	0.46	0.69	0.55	0.78	0.48	0.72
2008	0.68	0.85	0.50	0.72	0.55	0.79	0.49	0.75
2009	0.73	0.89	0.51	0.74	0.53	0.78	0.48	0.74
Total	0.69	0.87	0.51	0.74	0.56	0.80	0.52	0.78

Note: Values under column labeled *B* are the proportions of students who earned a B or higher course grade, and those under column labeled *C* are the proportions of students who earned a C or higher course grade.

Table 7 contains the proportion of successful students by student subgroup and college course.

Table 7

Proportion Successful, by Subgroup and College Course

	English Composition		College Algebra		Social Science		Biology	
Subgroup	*B*	*C*	*B*	*C*	*B*	*C*	*B*	*C*
Race/Ethnicity								
Asian	0.73	0.89	0.58	0.78	0.65	0.85	0.58	0.80
African American	0.53	0.80	0.37	0.63	0.36	0.64	0.29	0.59
Hispanic	0.65	0.84	0.48	0.71	0.50	0.77	0.43	0.72
Other	0.63	0.82	0.47	0.70	0.52	0.75	0.49	0.75
White	0.72	0.89	0.53	0.76	0.58	0.82	0.55	0.81
Income Level								
Low income	0.62	0.82	0.45	0.70	0.47	0.72	0.45	0.72
Middle/high income	0.72	0.89	0.53	0.76	0.58	0.82	0.54	0.80
Gender								
Male	0.63	0.84	0.45	0.70	0.52	0.77	0.48	0.76
Female	0.74	0.89	0.55	0.78	0.59	0.82	0.54	0.80

Across racial/ethnic classifications, White and Asian students had the highest success rates – B criterion in Biology and the social science courses had the largest subgroup differences (relative to other racial/ethnic subgroups). We observed that the success rates for students from middle/high income families were higher than students from low-income families, and the differences between the income subgroups were somewhat consistent across the courses. Compared to females students, male students had lower success rates in all four first-year college courses with the largest gender differences occurring for the B criterion in English Composition and College Algebra.

Overall Achievement Gaps

Before examining trends in college achievement gaps over time, we summarized the subgroup differences in course success rates, conditioned on the other predictor variables. As described earlier, overall conditional probabilities of success for each subgroup can be derived from the main-effects multilevel logistic regression models.

Table 8 contains the conditional probabilities of success for each subgroup, course, and criterion level.[13]

Table 8

Conditional Probabilities of Course Success by Student Subgroup and College Courses

	English Composition		College Algebra		Social Science		Biology	
Subgroup	*B*	*C*	*B*	*C*	*B*	*C*	*B*	*C*
Race/Ethnicity								
Asian	0.73	**0.90**	0.56	0.80	0.64	0.85	0.60	**0.84**
African American	0.64	0.87	**0.47**	0.74	0.52	0.78	0.46	0.78
Hispanic	0.69	0.88	**0.49**	**0.75**	0.55	0.81	0.52	0.81
Other	0.66	0.86	0.44	0.71	0.53	0.79	0.50	0.80
White	0.70	0.89	0.48	0.75	0.58	0.82	0.54	0.84
Income Level								
Low income	0.63	0.84	0.48	0.73	0.51	0.76	0.47	0.75
Middle/high income	0.68	0.88	0.52	0.76	0.57	0.81	0.52	0.80
Gender								
Male	0.60	0.84	0.45	0.71	0.52	0.77	0.46	0.76
Female	0.71	0.89	0.56	0.78	0.56	0.80	0.53	0.79

Note: Bold fonts indicate that the probability of success for the subgroup is not statistically significantly different ($p>$ 0.05) than the probability for the reference subgroup.

In English Composition, achievement (conditional probability of success) gaps existed for male versus female, low-income versus middle/high-income students, African American students, and students of "other" racial/ethnic category relative to White students (Table 8). However, this study did not find a significant difference in the conditional probability of success for Asian students (at the C criterion), relative to the White students. At the B criterion, we observed the smallest conditional probabilities of success for male (0.60) and low-income (0.63) subgroups; and the biggest probabilities for female (0.71) and the Asian students (0.73) subgroups (see Table 8).

[13] This analysis tested for overall college achievement gaps over the 12-year study period, without regard to whether the sizes of the gaps may have changed over time.

In College Algebra, we found significantly large achievement gap for male students (relative to female students) and students of "other" race/ethnicity (compared to White students). Asian students had higher probabilities of success in College Algebra than any other racial/ethnic subgroup. Also, we saw a significant achievement gap for low-income (compared to middle/high-income) students. Unlike in other courses, our study did not find a statistically significant achievement gap between African American and White students, and between Hispanic and White students in College Algebra at the B criterion (Table 8).

Across all subgroups and criterion levels, statistically significant achievement gaps occurred in the Biology and social science courses at both the B and C criterion levels. However, we did not find a statistically significant gap between Asian and White students in Biology at the C criterion.

Trends over Time in Achievement Gaps

Table B-1 through Table B-4 in Appendix B contain the parameter estimates from the multilevel logistic regression models that included the interaction terms between cohort year and student subgroup. In all cases, HSGPA and ACT subject score showed a significant and positive prediction of college achievement. As described earlier, these variables are important to include in the models because we defined college achievement gaps as subgroup differences in achievement, net of pre-college academic achievement.

We used the interactions between subgroups and cohort year, in Tables B-1 through B-4, to estimate trends in achievement gaps from 1998 to 2009. We now turn our attention to trends of the achievement gaps for each subgroup of students.

Asian. Relative to White students, Asian students had higher base year probabilities of success in College Algebra and in the social science courses at both criteria. In the social science courses, the base year odds of success were 54% (B criterion) and 53% (C criterion) higher for Asian students relative to White students. However, over time, the gap between Asian and White students narrowed (Table B-3, Figure 1 below), and appears to have closed. In addition, over time, Asian students performed better than White students for the B criterion in English Composition (Table B-1).

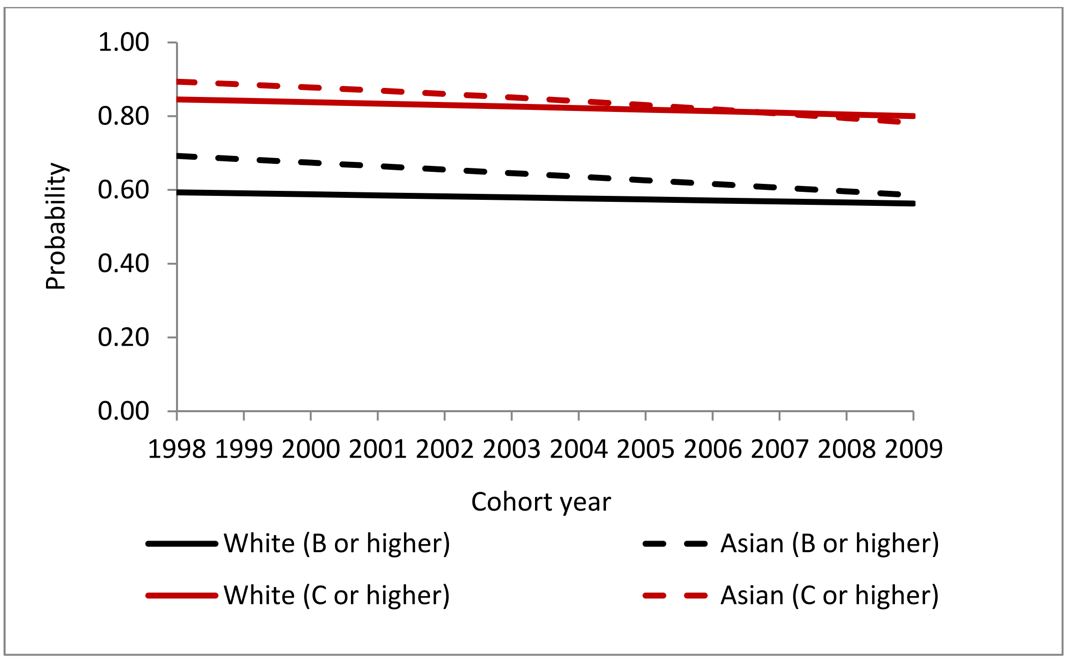

Figure 1. Probability of success in the social science courses for Asian and White students, 1998-2009.

In Biology, Asian students did not perform significantly different than the White students, and the pattern did not change over the twelve years.

African American. Relative to White students, African American students had smaller base year probabilities of achieving the B criterion in English Composition (a

23% less odds of success than the odds for White students, Table B-1), the social science courses (with odds of success at 13% less than the odds for White students, Table B-3), and Biology (with odds of success at 37% less than the odds for White students, Table B-4). The C criterion also showed similar results. Success probabilities for African American students were not significantly different than those for White students in College Algebra. The achievement gaps in English Composition between African American and White students remained unchanged from 1998 to 2009, but grew over the same period in the social science courses (Figure 2).

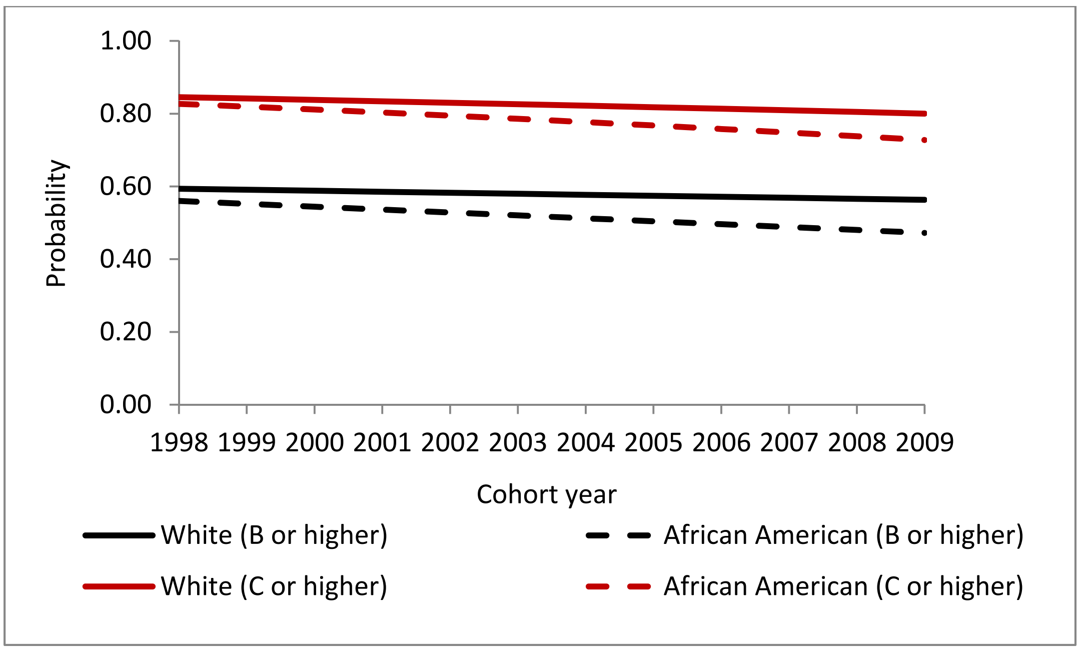

Figure 2. Probability of success in the social science courses for African American and White students, 1998-2009.

On the contrary, the achievement gap in Biology for African American students narrowed over the twelve year period (Figure 3).

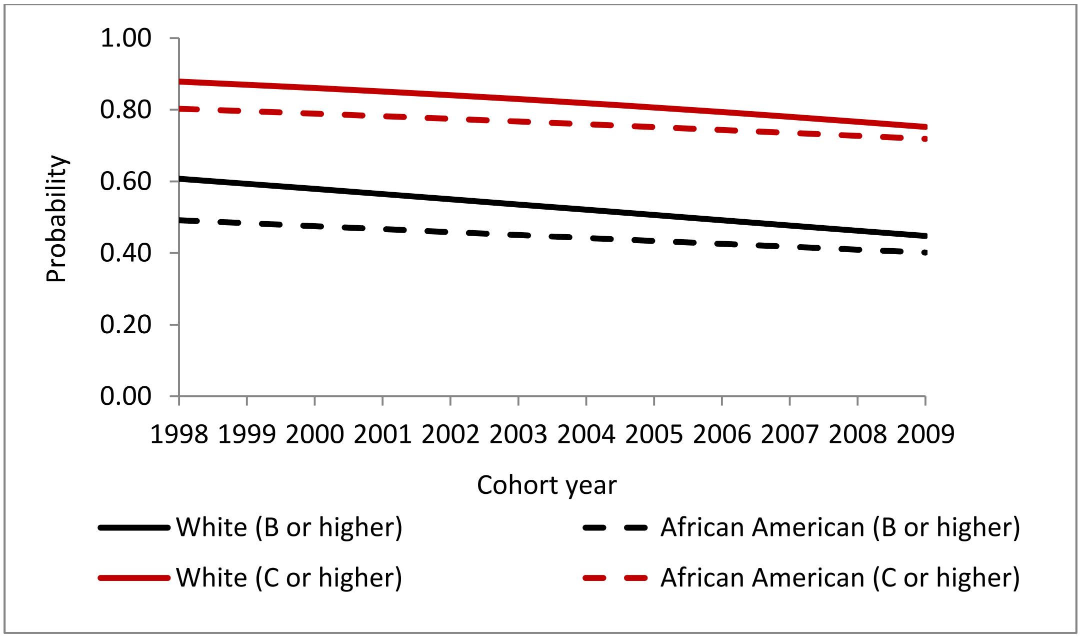

Figure 3. Probability of success in Biology for African American and White students, 1998-2009.

Hispanic. There were no significant base year achievement gaps for Hispanic students (relative to White students), except at the C criterion in Biology (odds of success was 25% less than the odds for White students, Table B-4). There were no significant trends in the achievement success rate differences between Hispanic and White students.

Other Race/Ethnicity. Relative to White students, base year odds of meeting the B criterion were lower for the "other" racial/ethnic classification of students by 18% in English Composition (Table B-1), 16% in College Algebra (Table B-2), 14% in the social science courses (Table B-3), and 16% in Biology (Table B-4). The differences were larger at the C criterion, with odds of success ranging from 28% less than the odds for White students in English Composition to 21% less than the odds for White students in College Algebra. The only significant change in the achievement gap over time was at the C criterion in English Composition. In this case, the achievement gap decreased slightly over time.

Income. Across all four courses, students from low-income families had lower odds of success in the base year (1998), compared to students from middle/high-income families. For students from low-income families, base year odds of success were 14% and 19% lower in English Composition (for B and C criterion levels, respectively), 11% and 15% lower in College Algebra, 18% and 24% lower in the social science courses, and 11% and 23% lower in Biology (see Table B-1 through Table B-4.) An examination of the interaction terms between income level and cohort year revealed that, from 1998 to 2009, the income achievement gap widened in English Composition (see Table B-1 and Figure 4) and the social science courses (Table B-3), but remained stable for College Algebra and Biology.

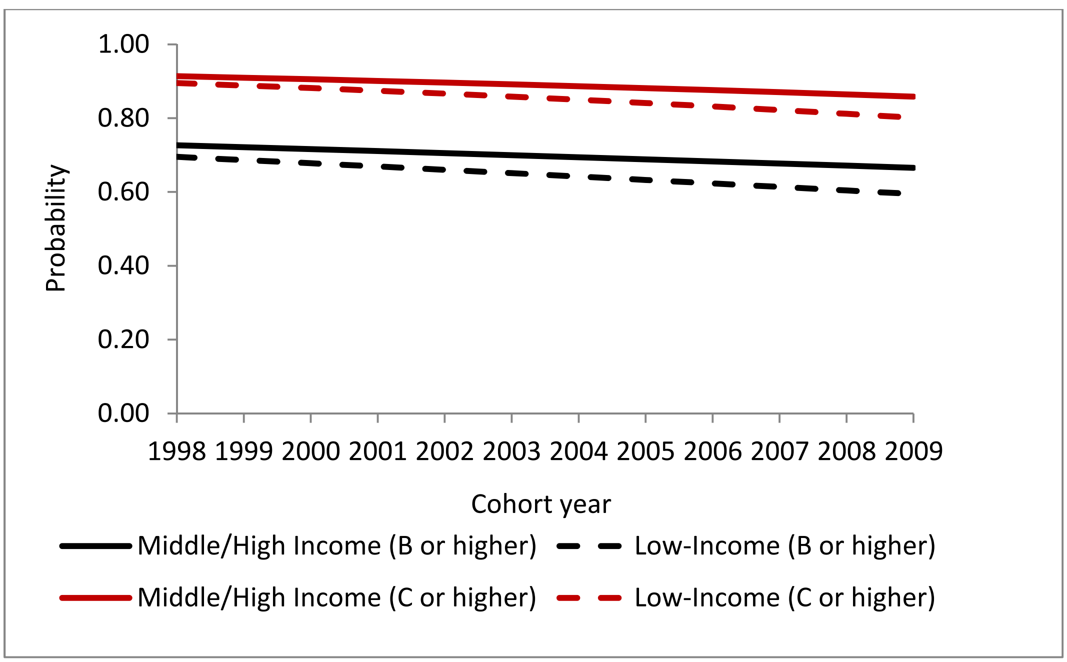

Figure 4. Probability of success in English Composition, by income level, 1998-2009.

Gender. Across all four courses, males were less likely (than females) to be successful at both criterion levels, indicating a consistent college achievement gap for males. Relative to female students, the base year odds of success for the B and C criteria for males were 41% and 40% lower in English Composition, 35% and 31% lower in College Algebra, 19% and 21% lower in social science courses, and 32% and 30% lower in Biology, respectively (Table B-1 through Table B-4).

The male-by-cohort year interaction term tested whether the gender achievement gap improved or worsened over the twelve years. Results indicated a decreasing gender achievement gap in English Composition (at the B and C criteria), in the social science courses at the C criterion, and in Biology at the B and C criteria levels. In English Composition, the gender gap at both criteria was present in 1998 and persisted, diminishingly, until 2009. In Biology, the gender achievement gaps at both criterion levels appeared to have closed by 2009.

Figure 5 below shows the trend in gender achievement gaps in Biology. The probability estimates are derived from the estimated logistic regression models. Figure 5 contrasts the probabilities for males and females over time, controlling for the other variables in the model (that is, race/ethnicity and income level).

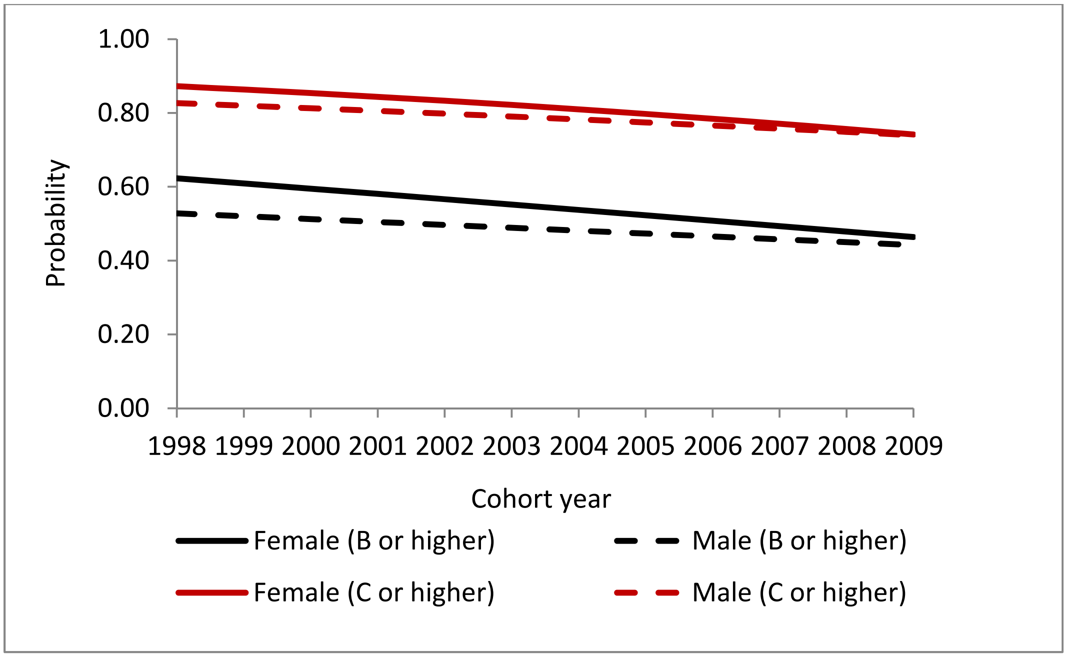

Figure 5. Probability of success in Biology[14], by gender, 1998-2009.

There was no indication of significant changes in the gender achievement gaps between 1998 and 2009 in College Algebra (Table B-2).

Discussion

In this study, we examined the existence and trends over time of achievement gaps among student subgroups in four types of first-year credit bearing college courses: English Composition, College Algebra, social science courses, and Biology. Student subgroups included: race/ethnicity (African American, Asian, Hispanic, Other, vs. White), income (low vs. middle/high), and gender (male vs. female). We defined success as achieving a B or higher, or C or higher course grades. We used multilevel logistic regression modeling to examine subgroup differences over time, while controlling for pre-college academic achievement.

[14] The probability estimates are derived from the estimated logistic regression models. Figure 5 contrasts the probabilities for males and females over time, controlling for the other variables in the model (that is, race/ethnicity and income level).

Reexamining the Research Questions

1. Do achievement gaps exist in first-year college courses by racial/ethnic, income, and gender student subgroups?

Our analysis measured subgroup differences, simultaneously controlling for the effects of correlated pre-college achievement and socio-demographic variables. For example, in measuring racial/ethnic gaps, we controlled for income level; likewise, we controlled for race/ethnicity when measuring income-based differences. Because underrepresented minority students are more likely than White students to have lower family income, this analysis approach was able to separate racial/ethnic gaps from income-based gaps.

Generally, we found achievement gaps in all four first-year college courses considered: English Composition, College Algebra, the social science courses, and Biology.

Controlling for pre-college achievement and the effects of income level and gender, African American students had lower success rates relative to White students in all courses, with the exception of College Algebra. The achievement gaps between White students and Hispanic students were small (odds ratios close to 1.00; differed by at most 0.03 odds points) and not statistically significant (Table B-1 through Table B-4). This showed that Hispanic students performed as well as White students. Students of the "other" racial/ethnic categories (American Indian/Alaskan Native, Other, and Multiracial students) were less likely to succeed, relative to White students, in all four courses. Asian students were more likely, than the White students, to earn a B or higher grade in all four courses (Table 8). Prior research reached similar conclusions on the existence of race/ethnicity-based academic achievement gaps (Young, 2001; Culpepper & Davenport, 2009; Noble, 2003; Miller, 1995).

The income achievement gaps were very consistent across all four courses, with differences (between middle/high-income and low-income students) in conditional probabilities of obtaining a B or higher grade ranging from 0.04 in College Algebra to 0.06 in the social science courses (Table 8). We found that income achievement gaps in first-year English Composition (Figure 4), and the social science courses, widened from 1998 through 2009.

After controlling for pre-college academic achievement (HSGPA and ACT scores), males were less likely than females to succeed in all of the college courses, resulting in a gender achievement gap. The achievement gap was especially large in English Composition and College Algebra. Overall, these findings are consistent with previous research that showed the existence of a college achievement gap between males and females (Young, 2001; Bridgeman & Wendler, 1991). Although previous research suggest that females score lower in Mathematics and Science (Mikyake et al., 2010; Robelen, 2012), this study found that female students outperformed male students in all of the first-year college courses considered, College Algebra and Biology included.

2. Did the sizes of the college achievement gaps change between 1998 and 2009?

We tested a total of 40 interaction effects (20 for the B criterion, 20 for the C criterion).[15] These interactions represent changes in the size of the achievement gaps over time for each subgroup and in each course. Of these 40, 14 were statistically significant (Tables B-1 through B-4). Of the 14 that were significant, 7 were positive, indicating that

[15] Forty interaction tests result from five subgroups (not including Asian students because they performed as well as White students), four courses, and two criterion levels.

the gaps grew smaller over the time period. So there is evidence that the size of some gaps changed between 1998 and 2009, but the size and direction of the changes varied across courses and subgroups.

In English Composition, the most striking trend was for the income subgroup, where the gap between low and middle/high-income students widened over time. For all subgroups of students considered, college achievement gaps in College Algebra remained stable from 1998 through 2009. In the social science courses, the gaps increased over time for African American versus White students, and for low-income versus middle/high income students. In Biology, the gaps decreased significantly for male compared to female students, and for African American students compared to White students. A report on achievement gap (Klein, 2009) concluded that the racial/ethnic achievement gap can be closed.

Some of the conclusions in this study are consistent with previous research on related areas. Male student underachievement in college relative to female students is consistent with the papers reviewed by Young (2001). Also, Dee (2006) and Robinson and Lubienski (2011) pointed to an increased gender achievement gap in reading. Fletcher and Tienda (2010) showed that racial/ethnic differences in college achievement shrunk but persisted even after controlling for class rank and test scores. Another study found that academic growth from grade 8 to grade 12 varies by race/ethnicity: Asian students consistently grew more than Hispanic and African American students (ACT, 2012). Using a different income level cutoff, others have concluded that the K-12 income achievement gap widened substantially for a certain subgroup of children (Reardon, 2011). Furthermore, the study suggested that income-based achievement gaps did not grow "appreciably" as children progressed through school. Based on the results from this study; we conclude that income-based achievement gaps exist in college, even after controlling for prior academic achievement and student demographics.

Theories for College Achievement Gaps

Studies have partly attributed pre-college racial/ethnic achievement gaps to under-resourced and understaffed schools (Carey, 2004). There is also a tendency for students in underrepresented racial/ethnic subgroups to not be assigned to sufficiently rigorous, higher level college-preparatory coursework (The Education Trust, 1999). The college achievement gap may be due to cultural, social, or institutional factors (Young, 2001; Zwick & Sklar, 2005). For example, racial/ethnic minority students on a less racially-diverse campus may experience feelings of anxiety and be less socially engaged (Carter, 2006). On the other hand, compared to their peers attending institutions with substantially large number of White students, African American students attending historically black colleges exert greater effort and involvement in academic activities such as writing experiences, interaction with faculty, and interaction with peers based on course content (DeSousa & Kuh, 1996).

Various explanations have been offered for income-based K-12 achievement gap that might also help explain the income-based college achievement gaps we observed. For example, higher-income parents spend more time and resources on their children's cognitive development compared with low-income parents. This finding may contribute to the growing income achievement gap (Reardon, 2011). Higher-income parents might also have higher expectations of their children's educational achievement. Others studies have proposed that, in addition to fewer home resources, low-income children do not regulate their emotions and behavior as well as middle/high-income children, contributing to weaker academic performance (Evans & Rosenbaum, 2008). We observed rising achievement gaps in English Composition and the social science courses, but not in College Algebra or Biology. It is possible that trends over time in income-based achievement gaps are an artifact of economic inflation: our study defined low-income subgroup as "less than $30,000" in annual family income, and one would presume that students in this income category would be more financially impaired in 2009 relative to 1998. However, if our findings were an artifact of economic inflation, it is plausible to assume that it would lead to increasing gaps in all four courses taken by the students in the subgroups studied. Another possible explanation for the income-based college achievement gap is the increasing cost of higher education, fueled, partly, by a drop of state support for education and a reduction in student financial aid. According to a study done at the *National Center for Public Policy and Higher Education* (Trombley, 2003), from 2001 to 2003, tuition and mandatory fees at four-year public institutions rose in every state. Additionally, all but two states – Maine and California – saw an increase in tuition and mandatory fees for community colleges. With the increasing cost of college education, we would expect to see an increase in the number of hours that low-income students need to work for pay, which could lead to lower grades and an increased achievement gap.

A review of 37 studies (Young, 2001) suggested that the gender achievement gap may be due to different course selection by male and female students and/or differences in the construct validity of college admissions tests. Because we studied specific types of college courses rather than overall first-year college GPA, course selection does not explain the gender achievement gap we observed. Another possibility is that certain behaviors, such as skipping class or failing to turn in assignments, may be more common among men (Young, 2001). These behaviors directly influence HSGPA and, for males, may lead to overprediction of college course grades from HSGPA. In addition, research confirms that male students enter college with lower levels of the academic-related behaviors needed for college success. For example, among entering college students who took the ACT ENGAGE™ College assessment, males scored 0.47 standard deviations lower than females on the Academic Discipline scale.[16] Further, Academic Discipline scale scores are incrementally predictive of grades in first-year college courses, after controlling for HSGPA, ACT scores, gender, race, socioeconomic status, and institutional effects (Robbins, Allen, Casillas, Peterson, & Le, 2006). Thus, the behaviors measured by the ACT ENGAGE College assessment may explain some of the gender achievement gap.

Theories hold that achievement gaps are explained by a combination of social, non-academic (e.g., psychological or psychosocial), demographic, cultural, and institutional factors. Interventions to reduce the gaps have been multi-faceted. For example, Glenn and Van Wert (2010) put forth a variety of interventions aimed at tackling the deficiencies in male performance in K-12; Offutt (2012) suggested addressing underperformance due to loss of learning during the summer; Cooper (2011) proposed starting the process of closing the Hispanic college achievement gap at home; Mikyake et al. (2010) advocated for psychological intervention; and Brown and Lee

[16] The Academic Discipline scale of the ACT Engage College assessment measures the amount of effort a student puts into schoolwork and the degree to which a student sees him-/herself as hardworking and conscientious. The female-male difference of 0.47 standard deviations is based on a sample of over 25,000 females and over 20,000 males.

(2005) recommended reducing stereotypes and stigma consciousness about college success of African American and Hispanic students. Others have encouraged more active roles of schools, colleges, and society (Schmidt, 2007; Scales, Roehlkepartain, Neal, Kielsmeir, & Benson, 2006) in closing the gaps.

Limitations and Conclusion

While the study included over 100 postsecondary institutions and over 330,000 students, the sample was not drawn randomly from the population of all first-year college students. Therefore, there is no guarantee that the findings are representative of the universe of postsecondary education in the U.S. Compared to the population of 2009 ACT-tested college freshmen, the study sample contained fewer African American, Hispanic, and low-income students.

This analysis relied on student self-reported data, including high school GPA, race/ethnicity, family income, and gender. Studies have shown that students self-report their high school grades with varied degrees of accuracy (ACT, 2013; Mattern et al., 2009; Sawyer et al., 1988). However, some of these variables may have been reported with error in a way that would bias the results. In addition, there may be variables that were not included that would help explain the college achievement gaps or the trends over time. For example, additional student factors such as personality and psychosocial factors might explain some of the gaps.

The analysis also did not examine differences in the gaps or trends across different types of institutions. The analysis did account for institutional effects through the use of the hierarchical model with institution-specific intercepts, but it is possible that the size of the gaps or the trends over time could also be explained by institutional characteristics such as type (2-year vs. 4-year), control (public or private), size, region or state, and selectivity. Future research could examine the link between degree of racial/ethnic and income diversity on campus and size of the achievement gaps.

This study examined the existence of student subgroup-based college achievement gaps in four first-year credit-bearing courses: English Composition I, College Algebra, Biology, and social science courses. The student subgroups examined include race/ethnicity, income, and gender. In addition, we tested for trends in gaps from 1998 through 2009 – a twelve-year period. We found that for some student subgroups, the sizes changed over time. This research did not focus on the possible causes of achievement gaps or ways to close them. However, results of our study suggest that efforts to close the college achievement gaps are still necessary.

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Appendix A

Technical Details of Multilevel Logistic Regression Models

Student Level Regression – Level 1 Model

$$\begin{aligned}
\text{logit}\left(P[Y_{ij} = 1]\right) = \log\left(\frac{P[Y_{ij} = 1]}{1 - P[Y_{ij} = 1]}\right) \\
&= \beta_{0j} + \beta_1(\text{HSGPA}_{ij}) + \beta_2(\text{ACT}_{ij}) + \beta_3(\text{Male}_{ij}) + \beta_4(\text{LowIncome}_{ij}) \\
&+ \beta_5(\text{Asian}_{ij}) + \beta_6(\text{AfricanAmerican}_{ij}) + \beta_7(\text{Hispanic}_{ij}) + \beta_8(\text{Other}_{ij}) \\
&+ \beta_9(\text{Year}_{ij}) + \beta_{10}(\text{Male}_{ij} * \text{Year}_{ij}) + \beta_{11}(\text{LowIncome}_{ij} * \text{Year}_{ij}) \\
&+ \beta_{12}(\text{Asian}_{ij} * \text{Year})_{ij} + \beta_{13}(\text{AfricanAmerican}_{ij} * \text{Year}_{ij}) \\
&+ \beta_{14}(\text{Hispanic}_{ij} * \text{Year}_{ij}) + \beta_{15}(\text{Other}_{ij} * \text{Year}_{ij}) + \varepsilon_{1ij}
\end{aligned}$$

Institution Level Regression – Level 2 Model

$$\beta_{0j} = \beta_{01} + \varepsilon_{2j}$$

where:

Y_{ij} is an indicator of success in the first-year credit bearing college course grade for the *i*th student in the *j*th institution.

β_{0j} is the intercept for the *j*th institution. β_{01} is the mean intercept across institutions.

$\beta_1 \dots \beta_{15}$ are the coefficients of the predictors.

ε_1 and ε_2 are random errors at the student level and institution level, respectively. These errors are assumed to be independent and normally distributed.

* denotes multiplication of variables for interaction terms.

Appendix B

Multilevel Logistic Regression Models

Table B-1

Multilevel Logistic Regression Models for English Composition I

	B Criterion				C Criterion			
Predictor Variable	*Est.*	*SE*	*OR*		*Est.*	*SE*	*OR*	
Intercept	1.360	0.047		*	2.749	0.074		*
Pre-college achievement								
HSGPA	0.604	0.006	1.83	*	0.571	0.007	1.77	*
ACT English score	0.284	0.006	1.33	*	0.058	0.008	1.06	*
Race/ethnicity								
Asian	-0.025	0.075	0.98		-0.041	0.100	0.96	
African American	-0.266	0.037	0.77	*	-0.180	0.046	0.84	*
Hispanic	-0.088	0.064	0.92		-0.127	0.081	0.88	
Other	-0.196	0.036	0.82	*	-0.335	0.044	0.72	*
Low income	-0.154	0.023	0.86	*	-0.216	0.030	0.81	*
Male gender	-0.534	0.020	0.59	*	-0.506	0.027	0.60	*
Cohort year	-0.026	0.003	0.97	*	-0.051	0.004	0.95	*
Interactions								
Asian x year	0.029	0.013	1.03	*	0.024	0.017	1.02	
African American x year	-0.005	0.006	1.00		-0.006	0.007	0.99	
Hispanic x year	0.004	0.010	1.00		-0.001	0.012	1.00	
Other race/ethnicity x year	-0.003	0.006	1.00		0.014	0.007	1.01	*
Low income x year	-0.014	0.004	0.99	*	-0.017	0.005	0.98	*
Male x year	0.010	0.003	1.01	*	0.017	0.004	1.02	*
School variance	0.152	0.025		*	0.384	0.064		*

Note: *Est*. is the estimated regression coefficient, *SE* is the standard error of the estimate, *OR* is the odds ratio associated with a one unit increase in the predictor. The reference subgroup for race/ethnicity was White students. An asterisk (*) indicates statistical significance at $p < 0.05$.

Table B-2

Multilevel Logistic Regression Models for College Algebra

	B Criterion				C Criterion			
Predictor Variable	*Est.*	*SE*	*OR*		*Est.*	*SE*	*OR*	
Intercept	0.329	0.072		*	1.594	0.078		*
Pre-college achievement								
HSGPA	0.664	0.008	1.94	*	0.576	0.008	1.78	*
ACT Mathematics score	0.539	0.008	1.71	*	0.411	0.010	1.51	*
Race/ethnicity								
Asian	0.280	0.101	1.32	*	0.271	0.118	1.31	*
African American	-0.063	0.056	0.94		-0.085	0.056	0.92	
Hispanic	0.056	0.090	1.06		0.020	0.097	1.02	
Other	-0.177	0.049	0.84	*	-0.238	0.052	0.79	*
Low income	-0.121	0.032	0.89	*	-0.167	0.035	0.85	*
Male gender	-0.435	0.028	0.65	*	-0.370	0.031	0.69	*
Cohort year	-0.019	0.004	0.98	*	-0.037	0.004	0.96	*
Interactions								
Asian x year	0.011	0.016	1.01		-0.006	0.019	0.99	
African American x year	0.002	0.008	1.00		0.000	0.008	1.00	
Hispanic x year	-0.001	0.014	1.00		-0.003	0.015	1.00	
Other race/ethnicity x year	0.005	0.008	1.00		0.005	0.009	1.01	
Low income x year	-0.007	0.005	0.99		-0.002	0.006	1.00	
Male x year	-0.002	0.005	1.00		0.000	0.005	1.00	
School variance	0.238	0.048		*	0.275	0.056		*

Note: *Est*. is the estimated regression coefficient, *SE* is the standard error of the estimate, *OR* is the odds ratio associated with a one unit increase in the predictor. The reference subgroup for race/ethnicity was White students. An asterisk (*) indicates statistical significance at $p < 0.05$.

Table B-3

Multilevel Logistic Regression Models for the Social Science Courses

	B Criterion				C Criterion			
Predictor Variable	*Est.*	*SE*	*OR*		*Est.*	*SE*	*OR*	
Intercept	0.583	0.047		*	1.951	0.041		*
Pre-college achievement								
HSGPA	0.687	0.006	1.99	*	0.585	0.007	1.80	*
ACT Reading score	0.445	0.006	1.56	*	0.314	0.007	1.37	*
Race/ethnicity								
Asian	0.431	0.065	1.54	*	0.428	0.084	1.53	*
African American	-0.137	0.041	0.87	*	-0.134	0.042	0.87	*
Hispanic	-0.030	0.058	0.97		-0.120	0.067	0.89	
Other	-0.150	0.034	0.86	*	-0.272	0.039	0.76	*
Low income	-0.203	0.024	0.82	*	-0.270	0.027	0.76	*
Male gender	-0.205	0.020	0.81	*	-0.233	0.024	0.79	*
Cohort year	-0.011	0.003	0.99	*	-0.028	0.003	0.97	*
Interactions								
Asian x year	-0.031	0.010	0.97	*	-0.049	0.013	0.95	*
African American x year	-0.021	0.006	0.98	*	-0.025	0.006	0.98	*
Hispanic x year	-0.018	0.009	0.98		0.000	0.011	1.00	
Other race/ethnicity x year	-0.006	0.006	0.99		0.009	0.006	1.01	
Low income x year	-0.010	0.004	0.99	*	-0.011	0.004	0.99	*
Male x year	0.009	0.003	1.01		0.012	0.004	1.01	*
School variance	0.250	0.033		*	0.161	0.022		*

Note: *Est*. is the estimated regression coefficient, *SE* is the standard error of the estimate, *OR* is the odds ratio associated with a one unit increase in the predictor. The reference subgroup for race/ethnicity was White students. An asterisk (*) indicates statistical significance at $p < 0.05$.

Table B-4

Multilevel Logistic Regression Models for Biology

	B Criterion				C Criterion			
Predictor Variable	*Est.*	*SE*	*OR*		*Est.*	*SE*	*OR*	
Intercept	0.691	0.105		*	2.291	0.112		*
Pre-college achievement								
HSGPA	0.759	0.012	2.14	*	0.624	0.012	1.87	*
ACT Science score	0.528	0.012	1.70	*	0.406	0.013	1.50	*
Race/ethnicity								
Asian	0.125	0.135	1.13		-0.059	0.163	0.94	
African American	-0.470	0.081	0.63	*	-0.575	0.078	0.56	*
Hispanic	-0.128	0.117	0.88		-0.290	0.128	0.75	*
Other	-0.172	0.062	0.84	*	-0.255	0.071	0.78	*
Low income	-0.120	0.042	0.89	*	-0.263	0.048	0.77	*
Male gender	-0.390	0.038	0.68	*	-0.361	0.045	0.70	*
Cohort year	-0.059	0.005	0.94	*	-0.079	0.006	0.92	*
Interactions								
Asian x year	0.019	0.023	1.02		0.018	0.027	1.02	
African American x year	0.025	0.013	1.03	*	0.037	0.012	1.04	*
Hispanic x year	0.006	0.020	1.01		0.016	0.021	1.02	
Other race/ethnicity x year	0.004	0.011	1.00		0.001	0.012	1.00	
Low income x year	-0.012	0.008	0.99		0.001	0.008	1.00	
Male x year	0.027	0.007	1.03	*	0.032	0.007	1.03	*
School variance	0.391	0.091		*	0.431	0.102		*

Note: *Est*. is the estimated regression coefficient, *SE* is the standard error of the estimate, *OR* is the odds ratio associated with a one unit increase in the predictor. The reference subgroup for race/ethnicity was White students. An asterisk (*) indicates statistical significance at $p < 0.05$.