# Importance of Undergraduate Research for Minority Persistence and Achievement in Biology

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*Introduction*

Low graduation rates in science fields are a significant problem in the United States. Fewer than half of those who entered undergraduate science and engineering programs in the early 1990s completed those programs (Center for Institutional Data Exchange and Analysis, 2001; U.S. Department of Education & National Center for Education Statistics, 2000). During the past decade, attrition from the sciences was associated with a shortage in the labor pool of science teachers and science and health professionals (National Science Foundation, 2003; Seymour & Hewitt, 1997). Although the number of science degrees awarded in the U.S. has increased in recent years, other countries, such as China and the United Kingdom, have increased their science degree numbers much more dramatically (National Science Board, 2008). In the natural sciences, China has more than tripled its number of

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first university degrees while the U.S. has only seen a slight incline in the past decade (National Science Board, 2008). Low numbers of educated workers in the natural sciences will affect our ability to remain competitive in rapidly changing biotechnology and biomedical global economies. In addition, increasing the pool of biomedical researchers and health professionals becomes increasingly important as our population grows and simultaneously lives longer.

Diversifying participation in scientific careers is also a pressing national concern. In 2000, Whites made up 75% of all life and physical scientists, Asians made up 16%, and Hispanics and African Americans each made up only 3% (National Science Foundation, 2004). Despite increasing enrollment in science and engineering majors, African Americans, Hispanics, and American Indians/Alaska Natives (underrepresented minorities) have lower graduation rates in those majors compared to Whites and Asians, (U.S. Department of Education & National Center for Education Statistics, 2000). Only 2.5% of underrepresented minority 24-year-olds[1] had earned a bachelor's degree in the natural sciences in 2000, compared with 6% of Whites (National Science Board, 2004). As the U.S. population shifts toward an increasingly multiracial society, the racial/ethnic gap in science degree completion predicts a severe shortage of diverse scientific workers (National Academy of Sciences, 2005).

Biology majors constituted the largest segment of natural science undergraduate degrees and 17% of all baccalaureate science degrees in 2005 (National Science Board, 2008). Differences by race/ethnicity persist in biology at the baccalaureate level (National Science Board, 2008; National Science Foundation, 2007), but they are exaggerated at higher levels of educational attainment. Although underrepresented minorities earn 13% of bachelor's degrees in biology, they earn only 8% of master's and 5% of doctoral degrees (National Science Foundation, 2006a, 2006b). Additionally, the proportion of U.S. citizens with biology PhDs is declining, while the number of U.S. trained non-resident aliens in biology is increasing (National Science Board, 2008). Therefore, the labor pool in the biological sciences may continue to diminish in diversity.

Access to graduate education is limited to those who excel at the undergraduate level. For that reason, a number of undergraduate educational intervention programs have been implemented by federal government agencies and private organizations during the past 30 years to increase the number of underrepresented minority students who are credible candidates for post-graduate study. The intervention programs seek both to encourage and to enable students to continue their educations. A common strategy of these programs is to focus on individual research experiences and financial support. The implicit assumption is that "when students are provided the opportunity to engage in state-of-the-art biomedical research, with appropriate facilities, support and mentorship, their appetite will be whetted to enter a career in biomedical research" (National Institutes of Health, 2007). In biology, this assumption is also supported by the need to incorporate undergraduate research opportunities in biology education to prepare students for rapid changes in biological research, technology, and modeling (National Research Council & Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, 2003). Although significant resources have been expended on such programs, few studies have rigorously investigated their efficacy. This dearth of research, coupled with the persistence of racial/ethnic disparities in the sciences, resulted in an NIH-funded initiative to build an empirical base of evidence upon which new interventions can be developed and existing interventions can be improved.

This study is part of that NIH-funded initiative, using the University of California, Davis (UC Davis) as a model system to study the role of undergraduate research participation in biology persistence and performance among a diverse group of students. UC Davis provides an illustrative campus to study this topic for several reasons. First, UC Davis is one of the nation's leading producers of baccalaureate degree recipients who eventually go on to obtain doctoral degrees in science and engineering fields (National Science Foundation, 2007). UC Davis is also the leading granter of baccalaureate biology and biomedically-related degrees in the nine-campus University of California (UC) system, having granted 21% of the UC system's baccalaureate biology degrees in 2007 (California Postsecondary Education Commission, 2008). UC Davis ranks third nationwide in providing the largest number of science and engineering bachelor's degrees among females (National Science Foundation, 2008).

Second, the UC Davis student body reflects that of other diverse UC campuses, although it has a slightly smaller percentage of Hispanic students compared to the entire UC system population (Student Affairs Admissions, 2008). UC Davis students are 39% non-Hispanic White, one third Asian/Pacific Islander, 10% Latino/Chicano, 2.5% African American, and about 7% non-resident aliens or of another race/ethnicity. Filipinos, who retained access to special services in the UC system due to their relatively low graduation rates, comprise 4% of both the student population of UC Davis and the UC system as a whole (California Postsecondary Education Commission, 2008). The UC system is reflective of California's increasingly non-White population, which in turn forecasts changes in the national population profile (University of California Undergraduate Work Team of the Study Group on University Diversity, 2007).

Third, UC Davis provides ample opportunities to engage in biology research. Faculty in the colleges of Biology, Agriculture and Environmental Sciences, and Letters and Science and in the Schools of Medicine and Veterinary Medicine sponsor undergraduates in research by enrolling them in research courses. An additional route to undergraduate research experiences at UC Davis is through an intervention program for underrepresented minorities in biology, the Biology Undergraduate Scholars Program (BUSP). BUSP facilitates paid research opportunities with faculty mentors, having matched a significant proportion of its approximately 1,000 participants with faculty engaged in biology-related research projects since its inception in 1988.

This study examines the statistical association between timing and duration of undergraduate research participation and college retention and performance in the biological sciences at UC Davis. Using longitudinal data from this large research university, we make a substantial contribution to the literature on college retention and persistence in science education. We also explore the relationship of undergraduate research participation with high academic achievement in biology, which is necessary to pursue graduate education and become future scientists, science workers, and health care professionals. In the following section, we detail existing research on this subject and our specific contributions to this body of literature.

## *Related Literature*

Evaluative studies on the benefits of undergraduate research in science career pathways have increased recently due to rising funding opportunities targeted towards improving retention in the sciences. However, most of these studies include descriptive accounts with small sample sizes, and they do not address issues of selection bias, intervening or omitted variables, and timing and duration of research over the entire undergraduate career (Alfred et al., 2005; Johnson, 2007; Lam, Ugweje, Mawasha, & Srivatsan, 2003; Levis-Fitzgerald & Denson, 2005). In a report on minority retention programs across the U.S., Gandara and Maxwell-Jolly (1999) stated that the limitations of these evaluative reports leave large gaps in our knowledge of the effects of these programs. A recent review of studies on the effectiveness of undergraduate research also listed the above issues as prevailing weaknesses in current empirical studies (Boylan, 2006). Without rigorous tests using large datasets to examine whether or not undergraduate research participation is positively associated with persistence and performance in the sciences, net of prior background characteristics, it is difficult to adequately determine the extent of this association.

Despite a lack of comprehensive quantitative studies addressing the role of undergraduate research in retention and performance in the sciences, there are a number of qualitative studies on science undergraduate research programs at liberal arts colleges showing specific benefits of undergraduate research. Ethnographic studies at four liberal arts campuses found that undergraduate research can help counter students' negative perceptions of the sciences by facilitating opportunities for students to network with and obtain support from faculty, peers, and science professionals (Hunter, Laursen, & Seymour, 2007; Seymour, Hunter, Laursen, & Deantoni, 2004). In these ethnographic studies, students and faculty reported that undergraduate research provided a form of "cognitive apprenticeship" in the sciences, where students gained academic, practical, and professional skills necessary to develop a positive identity as a scientist and continue in a science career (Farmer, Buckmaster, & LeGrand, 1992; Hunter et al., 2007; Seymour et al., 2004). Undergraduate research also encouraged personal and intellectual development in the sciences, increased interest in the sciences, helped to refine career and graduate school paths, and improved scientific competence and skill sets, such as problem solving, critical thinking, and understanding theory and concepts in the sciences (Hunter et al.; Seymour et al.).

Other studies on the effects of science work experience or underrepresented minority intervention programs that include undergraduate research opportunities detail positive outcomes in helping students pursue science-related careers (Clewell et al., 2005; Maton, Hrabowski III, & Schmitt, 2000; Pascarella & Staver, 1985; Summers & Hrabowski III, 2006). In a national study of science bachelor-degree holders, Russell et al. (2007) showed that involvement in undergraduate research activities fostered greater understanding, confidence, and interest in science careers. Surveyed students and alumni who participated in undergraduate research programs at research institutions reported that working collaboratively with peers and faculty in a "hands-on" environment was important for developing skills and increasing their academic confidence (Bauer & Bennett, 2003; Levis-Fitzgerald & Denson, 2005).

Outside of the sciences, studies of liberal arts departments and professional schools at the University of Michigan demonstrate that undergraduate research is associated with lower attrition rates (Nagda, Gregerman, Jonides, von Hippel, & Lerner, 1998) and higher levels of graduate school attendance (Hathaway, Nagda, & Gregerman, 2002). These studies suggest that participation in undergraduate research can provide students, particularly underrepresented racial/ethnic minority students, with regular faculty contact, relationships fostering collaborative academic activities, and a positive peer advising culture. In engineering, undergraduate research participation positively influenced skill levels, job values, and life objectives at a small technical college, although racial/ethnic differences were not assessed (Hackett, Croissant, & Schneider, 1992). Hathaway et al. (2002) also found that undergraduate research increases opportunities to gain job recommendations from faculty and continue contact with faculty after graduation. However, we know little about the association between undergraduate research and retention and performance among science majors at large research universities, where institutional integration may be difficult due to the greater likelihood of a "cold" and competitive culture within the science major (Seymour & Hewitt, 1997).

Theoretically, involvement in academic or social programs and increased faculty and peer contact, regardless of major, have been identified as important for institutional integration and for retaining students in college (Tinto, 1993). Tinto suggests that social and academic integration strongly impact institutional commitment and the subsequent decision to persist or withdraw from the institution. He defines integration as a process in which the individual establishes membership in the institution through involvement in its academic or social life. He also distinguishes between social integration and academic, or intellectual, integration. The former represents the social ties that result from frequent interactions with college community members, while the latter focuses on the sharing of information, perspectives, and values common to other members of the institutional community.

Both types of integration can develop through formal and informal contact with faculty and peers that occur beyond the classroom in other institutional settings (Astin & Panos, 1969; Pascarella, 1980; Pascarella & Terenzini, 1977; Tinto, 1993). In particular, frequent and high-quality faculty-student interactions focused on developing the intellectual and academic interests of the student are positively associated with degree completion (Pascarella & Terenzini, 1977). These types of faculty-student interactions appear most beneficial among students with low prior institutional commitment, such as underrepresented minorities (Pascarella & Terenzini, 1979). In general, underrepresented minorities appear to be more sensitive to non-cognitive factors associated with retention, including increased academic confidence, faculty contact, positive faculty-student relationships, involvement in campus activities, and access to role models or advanced peers (Braddock II, 1981; Fischer, 2007; Grandy, 1998; Tracey & Sedlacek, 1984, 1987), which are often components of the undergraduate research experience (Bauer & Bennett, 2003; Hunter et al., 2007; Seymour et al., 2004). Evaluative studies of programs targeted towards underrepresented minorities also suggest that undergraduate research may increase the academic and social integration of underrepresented minorities because of the integrative and mentoring nature of undergraduate research programs (Clewell et al., 2005; Nagda et al., 1998).

However, other studies provide mixed evidence on the differential effects of research experience by race/ethnicity. One survey of science undergraduate research participants found that although effects of undergraduate research on potential pursuit of a science career tended to be strongest among Hispanics, and weakest among non-Hispanic Whites, most racial/ethnic group differences were nevertheless relatively small (Russell et al., 2007). Another survey found racial/ethnic differences to be non-existent in the effects of undergraduate research on plans to pursue postgraduate education in the sciences (Lopatto, 2004).

No previous study has examined racial/ethnic differences in the role of undergraduate research participation in the retention and performance of science majors in a large university, and there is limited quantitative research addressing the extent of this association in general. As shown above, most research on undergraduate research in the sciences focuses on the development of science career pathways or on developing skills necessary to pursue such careers, rather than providing tangible evidence as to the association between undergraduate research and retention and performance in the science major. Past studies on the benefits of undergraduate research are also limited in acknowledging the possible effects of timing and duration of undergraduate research participation. Many studies evaluate undergraduate science research programs that take place during the summer before the senior year (Hunter et al., 2007; Kardash, 2000; Seymour et al., 2004), while other studies lack any identification of the timing or duration of the undergraduate research program (Hakim, 1998; Levis-Fitzgerald & Denson, 2005).

Nagda et al. (1998) find that the effects of participation in a liberal arts research program available for first- and second-year students are strongest for second-year students compared to first-year students. Hurtado and colleagues (2008) also suggest that research opportunities early in the college career are important to attract and retain students in science research careers. A study on alumni perceptions of past undergraduate research experiences demonstrates that alumni from all majors reported greater amounts of enhanced skill levels when they participated in undergraduate research for longer periods of time (Bauer & Bennett, 2003). However, none of these studies evaluate or control for timing and duration throughout the entire college career to examine progress through degree obtainment; therefore, it is difficult to know how much timing and duration matter in college retention in the sciences.

To fill these gaps in the literature, we examine the association between timing and duration of undergraduate research participation and college retention and performance in the biological sciences using longitudinal data of biology majors at UC Davis. Our sample consists of all undergraduate students who entered UC Davis as freshmen during 1995–99 with declared majors in the biological sciences. Our study controls for main variables previously shown to influence college outcomes (Bowen & Bok, 1998; Cole & Barber, 2003). First, we control for the characteristics of individual students when they enter college: their demographic characteristics and pre-college academic performance levels, which include race/ethnicity, gender, socioeconomic status, high school grades, and SAT scores. Second, we eliminate institutional variability by limiting our study to a single large university campus. Lastly, we address factors that occur during college, such as completion of course sequences, grades in introductory courses, and duration and timing of undergraduate research.

### *Research Questions*

We examine the following research questions: Is participation in undergraduate research positively associated with graduation in any major and retention in biology? Since past research has linked undergraduate research to increased academic competence and confidence in the sciences (Bauer & Bennett, 2003; Hunter et al., 2007; Kardash, 2000; Levis-Fitzgerald & Denson, 2005; Seymour et al., 2004), is undergraduate research also associated with the academic performance of those who complete a major in biology? If so, do these associations differ for underrepresented racial/ethnic minorities compared to Whites and Asians? Lastly, how does the timing and duration of research relate to the above outcomes?

### *Data*

UC Davis's Student Affairs Research & Information (SARI) office provided us with transcript and admissions application data on all 7,664 students who entered UC Davis as freshmen during 1995–99 with a declared major in biology.[2] All cohorts are grouped together into one sample to gain more leverage from our data. In additional analyses, we fit models restricting the samples by cohort year and the substantive results were similar to models combining all cohorts together. We removed from the sample 486 students who lacked data on racial/ethnic identity; they most likely did not indicate race/ethnicity on their UC Davis application. We removed another 30 students who were financially independent of their families because we use financial aid indicators to measure socioeconomic status. These indicators are not comparable for financially independent students.

An additional 204 individuals lacked high school GPA and SAT scores in the SARI database. Since these observations comprised less than 3% of the sample, we used list-wise deletion to deal with the missing data. We also removed another 63 students who entered during the years 1995–97 but took longer than 7 years to graduate. Since students from the 1998–99 cohorts took a maximum of 7 years to graduate but those from the 1995–97 cohorts took a maximum of 10 years to graduate, we restricted the entire sample to a maximum of 7 years to ensure comparability across cohorts. Therefore, in all of our analyses, degree holders include students who took a minimum of 3 years and a maximum of 7 years to graduate. Taking into account all of the foregoing deletions, our sample size includes 6,834 students who entered UC Davis as freshmen majoring in the biological sciences. Of those 6,834 students, 5,626 (82%) obtained a baccalaureate degree and 2,532 (45%) obtained a degree in a biology major (see Table 1).

### *Analyses*

We use logistic regression to estimate three dichotomous dependent variables: the conditional probability of graduation in any major (overall graduation; 1 = yes, 0 = no), graduation in biology among baccalaureate-degree holders (persistence in biology; 1 = yes, 0 = no), and graduation in biology with a GPA of 3.0 or higher among biology-degree holders (performance in biology; 1 = yes, 0 = no). We use the entire sample of 6,834 to predict graduation in any major (Table 3). Models predicting graduation in biology use the sub-sample of 5,626 UC Davis graduates to predict persistence in the biology major (Table 4). Among the subsample of baccalaureate-degree holders, we use the sample of 2,532 students who graduated in biology to model graduation in a biology major with a 3.0 GPA or higher (Table 7). We use these final models to predict performance in biology and eligibility for professional or graduate school since most universities require a 3.0 GPA or higher to be admitted to professional or graduate school.

Logistic regression allows us to predict the odds of graduation outcomes based on the observed values of independent variables. In mathematical terms, we estimate the log-odds of the probability of an outcome occurring for each student *i*:

$$\text{Logit}(p_i) = \ln(p_i/1 - p_i) = \alpha + \beta_1 x_1 + \ldots + \beta_k x_{k,i}$$

We present coefficients in the odds metric, or the exponential function of the log-odds of each outcome, and 95% confidence intervals in parentheses. In the text, we also discuss findings using the odds metric.

### *Independent Variables*

We use two sets of independent variables: individual characteristics and research participation variables. We introduce individual characteristic variables as statistical controls, and then we focus on the research participation variables. Table 1 provides descriptive statistics, including means or percent for categorical variables and standard deviations, for all measures in the sample set of each outcome.

*Gender and race/ethnicity*. Females are coded as *1* and males are coded as *0*. We used the racial/ethnic categories from the University of California admissions application provided to us by SARI. These categories are coded as *1* for Asian, African American, Hispanic, Filipino, and Native American, with White the omitted category. About 20% of the 1995–99 entering biology students are members of underrepresented minority groups (Table 1). Underrepresented minority groups for UC Davis include African Americans, Hispanic Americans, and Native Americans/Alaska Natives (Student Affairs Research & Information, 2000).

*Socioeconomic status*. As a measure of socioeconomic status, we obtained data from UC Davis' Financial Aid office on Expected Family Contribution (EFC) to the student's yearly expenses and created dummy variables based on quartiles.[3] We used the quartile dummy variables rather than an interval scale because it was heavily skewed at the lower end (a majority of families who apply for financial aid had an EFC of under $10,000). Students with an EFC below $785 qualify in the less than 25th percentile range, and they are coded as *0* (the omitted category). The 25th–49th percentile range consists of students whose families contribute between $785 and $5,569 (coded as *1*). The 50th–74th percentile range consists of EFCs between $5,569 and $14,978 (coded as *1*). Lastly, the 75th–99th percentiles consist of an EFC of $14,978 or above (coded as *1*). Those who did not apply for financial aid are also coded as *1*. Examination of student-reported data on parental educational attainment suggests that those who did not apply for financial aid are most likely to be from middle or upper-class families who would not

TABLE 1
Descriptive Statistics for Each Sample Set

| | Graduation in any major ($n$ = 6,834) | | Biology degree ($n$ = 5,626) | | Biology degree restricted to intro. biology completers ($n$ = 3,076) | | Performance in biology ($n$ = 2,532) | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | *SD* | Mean | *SD* | Mean | *SD* | Mean | *SD* |
| *Dependent Variables* | | | | | | | | |
| Obtained a degree in any major | 0.82 | | | | | | | |
| Obtained a biology degree | | | 0.45 | | 0.79 | | | |
| Obtained a bio.degree w/ >/= 3.0 GPA | | | | | | | 0.59 | |
| *Independent Variables* | | | | | | | | |
| Female | 0.65 | | 0.67 | | 0.66 | | 0.66 | |
| Race/ethnicity | | | | | | | | |
| White [omitted] | 0.44 | | 0.44 | | 0.44 | | 0.44 | |
| Asian | 0.35 | | 0.36 | | 0.38 | | 0.38 | |
| African American | 0.03 | | 0.03 | | 0.02 | | 0.02 | |
| Hispanic | 0.12 | | 0.10 | | 0.09 | | 0.09 | |
| Filipino | 0.05 | | 0.06 | | 0.07 | | 0.07 | |
| Native American | 0.01 | | 0.01 | | 0.01 | | 0.01 | |
| Expected family contribution | | | | | | | | |
| < 25th percentile [omitted] | 0.19 | | 0.18 | | 0.17 | | 0.16 | |
| 25–49th percentiles | 0.20 | | 0.20 | | 0.20 | | 0.20 | |
| 50–75th percentiles | 0.20 | | 0.20 | | 0.21 | | 0.21 | |
| > 75th percentiles | 0.20 | | 0.21 | | 0.22 | | 0.22 | |
| No financial aid data | 0.22 | | 0.22 | | 0.21 | | 0.22 | |
| *High School Achievement* | | | | | | | | |
| GPA | 3.77 | 0.35 | 3.80 | 0.34 | 3.87 | 0.32 | 3.89 | 0.31 |
| SATI Math Score | 595 | 79 | 598 | 77 | 613 | 73 | 615 | 71 |
| SATI Verbal Score | 549 | 93 | 551 | 91 | 561 | 90 | 562 | 90 |
| *College Indicators* | | | | | | | | |
| Intro. biology GPA | | | | | 2.88 | 0.69 | 2.96 | 0.67 |
| Initial research during 1st two years | 0.05 | | 0.05 | | 0.06 | | 0.07 | |
| Initial research during third year | 0.05 | | 0.05 | | 0.08 | | 0.09 | |
| Initial research after third year | 0.21 | | 0.20 | | 0.30 | | 0.33 | |
| 1 term of research | 0.13 | | 0.15 | | 0.18 | | 0.18 | |
| 2–3 terms of research | 0.11 | | 0.13 | | 0.18 | | 0.20 | |
| >3 terms of research | 0.06 | | 0.08 | | 0.11 | | 0.12 | |

have qualified for financial aid. Some of these students may also be first-generation college students who are uninformed about financial aid, but we lack data on the college-generation status of these students.

*High school achievement*. High school GPA was a linear measure ranging from 2.3 to 4.6, but we broke it into a series of nominal percentile ranges based on each sample because it was heavily skewed toward higher GPAs, due to the selectivity of University of California admissions. This was especially true when we restricted the sample to baccalaureate-degree holders and biology-degree holders (see Table 1).[4] In all models, the 24th percentile or less category is the omitted category. We measure SAT I scores as interval variables with 10-point increments ranging from 200 to 800 for verbal scores and 250 to 800 for math scores.

*Timing of undergraduate research participation*. Our indicators for timing of undergraduate research are as follows: students who started undergraduate research during their first two years, during their third year, and after their third year are coded as *1*. These are students who passed at least one term of a "Special Study" course (listed as 99 or 199), which require consent from an instructor and, in the natural sciences and most other disciplines, are used to designate undergraduate research.[5] Among those coded as *1* depending on their timing of research, 110 of these students enrolled in Biology Undergraduate Scholars Program (BUSP) faculty-sponsored research and did not participate in 99 or 199 courses. Most (95%) of these BUSP students are underrepresented minorities. Each year, 150–200 new under-represented minority and other disadvantaged freshmen with an interest in majoring in the biological sciences are invited to participate in BUSP. About one-third of the eligible pool elects to participate in BUSP, resulting in an entering class of approximately 50–65 freshmen per year. BUSP-sponsored research is voluntary and strongly encouraged, and it is usually initiated during the first two years. Also, a majority of BUSP students participate in research for four terms or greater. We tried separating BUSP-sponsored research from credit-based research, but empirically there appeared to be no advantage to this separation. BUSP-sponsored and credit-based research had similar positive associations with college persistence and performance (data not shown).

In models predicting graduation with a baccalaureate degree in any major (Table 3), 306 students who took a 99 or 199 research course outside of the natural or physical sciences (such as in the Humanities or Social Sciences) are included in the timing and duration of undergraduate research measures. In models predicting persistence and performance in biology (Tables 5–7), our research indicators only include students who participated in research in the natural or physical sciences. However, in all models, research courses in Psychology are included in the research indicators, due to their strong emphasis on animal behavior studies at UC Davis. Students who did not participate in science research in models in Tables 5–7 are coded as *0*.

*Duration of undergraduate research participation*. We also measure duration of undergraduate research by total number of terms enrolled in 99 or 199 course credit or BUSP-sponsored research. We broke down the linear measure, which ranged from 0 to 16 terms, into a series of categorical measures coded as *1* for one term of research, *1* for two to three terms of research, and *1* for greater than three terms of research. Again, students who did not participate in any type of undergraduate research are coded as *0*.

*Introduction to Biology GPA*. In models restricted to completion of Introduction to Biology courses (Table 6), we also control for GPA in the Introductory Biology sequence (BIS1A, BIS1B, and BIS1C). This is a linear measure using 0.01 units ranging from 0.35 to 4.0.

In previous attempts at modeling the association between undergraduate research participation and graduation outcomes (not shown), we used a general indicator for student research: "ever participated in undergraduate research." We found a strong positive association between "ever participated in undergraduate research" and graduation, retention, and performance in biology. In models presented here, we separate "ever participated in undergraduate research" into measures representing the timing and duration of undergraduate research participation. This allows us to more precisely capture the relationship between undergraduate research participation and our graduation outcomes. However, due to the non-random assignment of students into undergraduate research, we cannot make causal claims regarding the influence of undergraduate research on college outcomes. Rather, we examine the statistical association between the timing and duration of undergraduate research participation and college retention and persistence and performance in the biological sciences, as well as whether or not this association differs between underrepresented racial/ethnic minorities and the White/Asian majority.

Table 2 provides descriptive statistics for the full sample of entering students (6,834), categorized according to participation in science research and racial/ethnic status (either underrepresented racial/ethnic minorities or White/Asian majority). These descriptive statistics show that men and women participate in research at about the same rate at UC Davis, and that African American and Filipino students participate at higher rates than their White and Asian peers, due to the large proportion of underrepresented racial/ethnic minority students involved in BUSP.[6] Research participants, both underrepresented racial/ethnic minority and White/Asian students, enter UC Davis with better high school academic preparation compared to those who do not participate in research.

TABLE 2
Research Participants Compared with Non-Participants, Separated by Racial/Ethnic Groupings

| | Underrepresented minorities | | | | White & Asian majority | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Science research | | No research | | Science research | | No research | | Total (full sample) | |
| Characteristic | *n* | % | *n* | % | *n* | % | *n* | % | *n* | % |
| *Demographic characteristics* | | | | | | | | | | |
| Male | 127 | 27% | 339 | 73% | 451 | 23% | 1,488 | 77% | 2,405 | 35% |
| Female | 284 | 29% | 692 | 71% | 927 | 27% | 2,527 | 73% | 4,430 | 65% |
| African American | 63 | 34% | 125 | 66% | | | | | 188 | 3% |
| Hispanic | 197 | 25% | 594 | 75% | | | | | 791 | 12% |
| Filipino | 138 | 37% | 233 | 63% | | | | | 371 | 5% |
| Native American | 12 | 15% | 67 | 85% | | | | | 79 | 1% |
| Asian American | | | | | 660 | 27% | 1,746 | 73% | 2,406 | 35% |
| White | | | | | 712 | 24% | 2,287 | 76% | 2,999 | 44% |
| *High School Achievement* | | | | | | | | | | |
| Mean high school GPA | 3.80 | | 3.63 | | 3.88 | | 3.77 | | 3.77 | |
| Mean math SAT | 569 | | 541 | | 621 | | 603 | | 596 | |
| Mean verbal SAT | 540 | | 518 | | 561 | | 554 | | 549 | |
| *College Indicators* | | | | | | | | | | |
| Mean EFC | $10,643 | | $8,011 | | $12,129 | | $11,493 | | $10,940 | |
| Initial sci. research during 1st two years | 142 | 35% | | | 166 | 12% | | | 308 | |
| Initial sci. research during third year | 49 | 12% | | | 262 | 19% | | | 311 | |
| Initial sci. research after third year | 220 | 53% | | | 944 | 69% | | | 1164 | |
| Mean number of terms of sci. res. (among research participants) | 3.81 | | | | 2.31 | | | | 2.66 | |
| Total | 411 | 6% | 1,019 | 15% | 1,372 | 20% | 4,033 | 59% | 6,834 | 100% |

## *Results*

*Graduation in any major*. Table 3 provides estimates on the odds of obtaining a baccalaureate degree, in any field of study, $n = 6{,}834$. Model 1 indicates that demographic characteristics, such as gender, race/ethnicity, and Expected Family Contribution to college expenses, are strongly associated with obtaining a baccalaureate degree at UC Davis. In Model 1, the odds of Hispanics earning a degree are about 60% [odds ratio = 0.61] that of Whites (the omitted reference category) and the odds of graduation for Native Americans are about one-third [odds ratio

= 0.33] that of Whites, consistent with national statistics during our timeframe (National Science Board, 2004). Females are about one and a half times as likely to graduate as males, even after controlling for prior achievement and research participation in the later models. In general, students with a low Expected Family Contribution to college expenses are less likely to graduate than students with a higher EFC.

After we control for high school achievement in Model 2, the gap between underrepresented minority students and Whites diminishes, but only slightly. The odds of graduation for Hispanics are about 25% lower than the odds of Whites [odds ratio = 0.75], while the odds of graduation for Native Americans remain about 60% lower than Whites [odds ratio = 0.39], holding gender, EFC, and high school achievement constant. On the other hand, Asian students are slightly but significantly more likely to graduate compared to Whites in all of the models. Similar to results from past research, high school GPA is significant in predicting successful graduation (Astin, 1993; Astin & Astin, 1992). In Model 2, students with a high school GPA of above 4.04 are almost twice as likely to graduate when compared with students with a high school GPA of 3.54 or below. Our indicators for socioeconomic status remain significant and show minimal changes in Models 2 through 4.

Models 3 and 4 introduce the undergraduate research participation variables. Among students who entered UC Davis in biology, those who participate in research during or after their third year and for one term of research or more are substantially more likely to graduate compared to students who do not participate in research.[7] In Model 3, students who participate in research in any major after their third year are almost fifteen times as likely to graduate as students who do not participate in research. Participation in research for more than three terms also increases the odds of graduation by over 900% in Model 4 [odds ratio = 10.73]. Even with the inclusion of our measures for undergraduate research participation, the odds of graduation for Native Americans are almost 60% lower than those of Whites [odds ratio = 0.38]. The odds of graduation for Hispanics are about 30% lower compared to Whites [odds ratio = 0.66].

In models not shown, we also added interaction terms for students in the underrepresented minority status categories (non-Asian and non-White, both including and not including Filipinos) and "ever participated in research," along with interactions between underrepresented minority status and the timing of research variables. These interaction terms were insignificant in all models, including models predicting persistence and performance in biology. This lack of a statistically significant interaction term may be due to the small cell sizes after breaking up

TABLE 3

Odds of Obtaining a Baccalaureate Degree in Any Major

| | *Model 1:* Social background | *Model 2:* High School achievement | *Model 3:* Research timing | *Model 4:* Duration of research |
|---|---|---|---|---|
| Female | 1.578*** | 1.552*** | 1.493*** | 1.486*** |
| | (1.408–1.748) | (1.377–1.727) | (1.319–1.667) | (1.313–1.658) |
| Asian | 1.289*** | 1.293*** | 1.255*** | 1.259*** |
| | (1.119–1.459) | (1.116–1.470) | (1.078–1.431) | (1.083–1.436) |
| African American | 0.707* | 1.024 | 0.894 | 0.796 |
| | (0.496–0.919) | (0.706–1.343) | (0.602–1.186) | (0.534–1.058) |
| Hispanic | 0.609*** | 0.748*** | 0.711*** | 0.664*** |
| | (0.510–0.708) | (0.620–0.875) | (0.585–0.837) | (0.546–0.781) |
| Native American | 0.326*** | 0.386*** | 0.390*** | 0.380*** |
| | (0.196–0.456) | (0.229–0.543) | (0.226–0.555) | (0.220–0.540) |
| Filipino | 1.225 | 1.221 | 1.080 | 1.027 |
| | (0.905–1.545) | (0.899–1.543) | (0.786–1.373) | (0.748–1.306) |
| EFC 25–49th percentiles | 1.530*** | 1.444*** | 1.491*** | 1.492*** |
| | (1.279–1.782) | (1.202–1.686) | (1.232–1.749) | (1.233–1.750) |
| EFC 50–75th percentiles | 1.720*** | 1.592*** | 1.616*** | 1.641*** |
| | (1.427–2.014) | (1.312–1.873) | (1.322–1.910) | (1.343–1.938) |
| EFC > 75th percentiles | 2.063*** | 1.892*** | 1.908*** | 1.919*** |
| | (1.693–2.434) | (1.538–2.247) | (1.540–2.275) | (1.550–2.288) |
| No financial aid data | 1.533*** | 1.497*** | 1.530*** | 1.549*** |
| | (1.279–1.788) | (1.237–1.757) | (1.256–1.804) | (1.272–1.825) |
| HS GPA 3.55–3.80 (25-49th percentiles) | | 1.491*** (1.277–1.705) | 1.448*** (1.235–1.662) | 1.428*** (1.217–1.638) |
| HS GPA 3.81–4.04 (50–74th percentiles) | | 1.644*** (1.400–1.888) | 1.507*** (1.277–1.738) | 1.499*** (1.270–1.727) |
| HS GPA > 4.04 (> 75th percentiles) | | 1.923*** (1.616–2.230) | 1.668*** (1.393–1.942) | 1.626*** (1.359–1.893) |
| SATI Math Score | | 1.002*** | 1.001** | 1.001** |
| | | (1.001–1.002) | (1.000–1.002) | (1.000–1.002) |
| SATI Verbal Score | | 1.000 | 1.000 | 1.000 |
| | | (0.999–1.001) | (0.999–1.001) | (0.999–1.001) |
| Initial research during 1st two years | | | 1.689*** (1.230–2.148) | |
| Initial research during third year | | | 5.890*** (3.372–8.408) | |
| Initial research after third year | | | 14.775*** (9.962–19.589) | |
| 1 term of research | | | | 4.768*** |
| | | | | (3.596–5.941) |
| 2–3 terms of research | | | | 7.446*** |
| | | | | (5.034–9.857) |
| > 3 terms of research | | | | 10.733*** |
| | | | | (5.485–15.981) |
| Observations | 6834 | 6834 | 6834 | 6834 |
| log likelihood | –3102.625 | –3062.648 | –2826.833 | –2860.524 |
| Deviance | 6205.250 | 6125.296 | 5653.666 | 5721.048 |
| BIC' | –81.889 | –117.694 | –562.836 | –495.453 |

*Notes.* Sample is restricted to UC Davis students who entered in a biology major.
95% confidence intervals are in parentheses.
*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$

the research terms by race/ethnicity. Nonetheless, these findings indicate that the association between participation in research and graduation in any major does not significantly differ for underrepresented minorities compared to Whites and Asians. However, since underrepresented minorities (particularly Hispanics and Native Americans) have a lower probability of graduation to begin with, participation in research may be more beneficial for underrepresented minorities compared to Whites and Asians. Table 4 shows that the predicted probabilities of graduation in any major for non-Filipino underrepresented minorities are below those of Whites and Asians regardless of undergraduate research status, and that the largest differences between those that do not participate in undergraduate research and those that participate in undergraduate research are among non-Filipino underrepresented minorities.

*Persistence in biology*. In Table 5, we estimate the odds of persistence in biology among UC Davis graduates who entered as freshmen with the intention of majoring in biology. The covariates considered in each model are almost identical to those in Table 3, except our research indicators include students who participated in science research only, rather than students who participated in research in any field.

First, Table 5 shows that gender does not appear to be significant in predicting odds of persistence in the biology major for those who earn a

TABLE 4
Predicted Probabilities of Graduation Outcomes by Race/Ethnicity

| | Predicted probabilities of graduation in any major, controlling for all variables | | |
|---|---|---|---|
| | No research | Research | Difference |
| White | 0.78 | 0.96 | 0.18 |
| Native Am. | 0.56 | 0.90 | 0.34 |
| Filipino | 0.79 | 0.96 | 0.17 |
| Hispanic | 0.65 | 0.93 | 0.28 |
| African Am. | 0.65 | 0.94 | 0.29 |
| Asian | 0.79 | 0.96 | 0.17 |
| | Predicted probabilities of graduation in biology among degree-holders, controlling for all variables | | |
| | No research | Research | Difference |
| White | 0.34 | 0.72 | 0.38 |
| Native Am. | 0.34 | 0.72 | 0.38 |
| Filipino | 0.37 | 0.74 | 0.37 |
| Hispanic | 0.25 | 0.65 | 0.39 |
| African Am. | 0.20 | 0.59 | 0.39 |
| Asian | 0.35 | 0.73 | 0.38 |

TABLE 5

Odds of Obtaining a Biology Degree

| | *Model 1:* Social background | *Model 2:* High School achievement | *Model 3:* Research timing | *Model 4:* Duration of research |
|---|---|---|---|---|
| Female | 0.926 | 0.942 | 0.905 | 0.902 |
| | (0.839–1.013) | (0.847–1.038) | (0.807–1.002) | (0.807–0.997) |
| Asian | 1.140** | 1.176** | 1.127* | 1.142* |
| | (1.021–1.259) | (1.044–1.307) | (0.994–1.261) | (1.009–1.275) |
| African American | 0.701** | 1.506** | 1.080 | 1.053 |
| | (0.492–0.909) | (1.029–1.983) | (0.710–1.449) | (0.697–1.410) |
| Hispanic | 0.740*** | 1.097 | 0.993 | 0.955 |
| | (0.622–0.858) | (0.910–1.284) | (0.812–1.174) | (0.784–1.126) |
| Native American | 0.854 | 1.153 | 1.238 | 1.147 |
| | (0.446–1.262) | (0.578–1.728) | (0.595–1.881) | (0.559–1.735) |
| Filipino | 1.312** | 1.403*** | 1.193 | 1.212 |
| | (1.054–1.570) | (1.116–1.691) | (0.932–1.453) | (0.952–1.471) |
| EFC 25–49th percentiles | 1.259** | 1.118 | 1.164 | 1.157 |
| | (1.071–1.446) | (0.943–1.293) | (0.971–1.358) | (0.969–1.346) |
| EFC 50–75th percentiles | 1.373*** | 1.191* | 1.269** | 1.254** |
| | (1.167–1.580) | (1.001–1.380) | (1.055–1.483) | (1.047–1.462) |
| EFC > 75th percentiles | 1.328*** | 1.103 | 1.125 | 1.123 |
| | (1.126–1.529) | (0.924–1.282) | (0.932–1.319) | (0.933–1.312) |
| No financial aid data | 1.118 | 1.024 | 1.055 | 1.074 |
| | (0.952–1.285) | (0.861–1.187) | (0.877–1.232) | (0.897–1.251) |
| HS GPA 3.58–3.83 (25–49th percentiles) | | 1.590*** (1.377–1.804) | 1.554*** (1.334–1.774) | 1.572*** (1.354–1.790) |
| HS GPA 3.84–4.05 (50–75th percentiles) | | 2.209*** (1.910–2.507) | 2.064*** (1.769–2.358) | 2.093*** (1.800–2.386) |
| HS GPA > 4.05 (> 75th percentiles) | | 3.159*** (2.729–3.589) | 2.843*** (2.434–3.252) | 2.875*** (2.469–3.281) |
| SATI Math Score | | 1.004*** | 1.004*** | 1.004*** |
| | | (1.004–1.005) | (1.003–1.005) | (1.003–1.005) |
| SATI Verbal Score | | 1.000 | 1.001 | 1.001 |
| | | (1.000–1.001) | (1.000–1.001) | (1.000–1.001) |
| Initial sci. research during 1st two years | | | 3.570*** (2.734–4.406) | |
| Initial sci. research during third year | | | 4.668*** (3.616–5.719) | |
| Initial sci. research after third year | | | 4.969*** (4.339–5.600) | |
| 1 term of sci. research | | | | 2.105*** |
| | | | | (1.826–2.384) |
| 2–3 terms of sci. research | | | | 3.710*** |
| | | | | (3.161–4.259) |
| > 3 terms of sci. research | | | | 4.870*** |
| | | | | (3.893–5.846) |
| Observations | 5626 | 5626 | 5626 | 5626 |
| log likelihood | –3847.647 | –3637.769 | –3337.111 | –3411.673 |
| Deviance | 7695.294 | 7275.538 | 6674.223 | 6823.346 |
| BIC' | 38.587 | –337.993 | –913.403 | –781.550 |

*Notes.* Sample is restricted to UC Davis graduates who entered in a biology major.
95% confidence intervals are in parentheses.
$*p < 0.10$; $**p < 0.05$; $***p < 0.01$

baccalaureate degree. In Model 1, Asians and Filipinos are also slightly, but significantly, more likely to graduate in biology compared to Whites [odds ratios = 1.14, 1.31, respectively]. Similar to Table 3, the EFC coefficients are also significant predictors of graduation with a biology degree, although they are slightly lower in magnitude and the “No Financial Aid” coefficient is insignificant.

In Model 2, high school achievement makes a substantial contribution to persistence in biology. The odds of obtaining a biology degree for a student in the highest GPA quartile (4.06 GPA or higher) are about 216% greater compared to those for a student in the lowest quartile (GPA of 3.57 or lower) [odds ratio = 3.16]. SAT I math scores also have a significant but modest influence on college persistence in biology. Every 10-point increase in math SAT I scores increases odds of graduation in biology by a factor of 1.004, or by 4%.

Once we control for high school achievement in Model 2, there is no significant difference in the odds of graduation in biology for Hispanics compared to Whites. African Americans, Asians, and Filipinos appear slightly and significantly more likely to graduate in biology compared to Whites after controlling for high school achievement (Model 2), although only the coefficients for Asians maintain significance after controlling for research participation (Models 3 & 4). Most other coefficients lose significance and are close to one after controlling for research participation, with the exception of high school achievement. Interaction terms between undergraduate research participation and underrepresented minority status were not significant in predicting graduation in biology in any of our models, so they were not included in the data presented. However, in Table 4, the predicted probabilities of Hispanics and blacks obtaining a biology degree are the lowest, regardless of participation in undergraduate research. Socioeconomic status also does not appear to be significant in Model 2, although students in the 50th–75th EFC percentile category are slightly more likey to obtain a biology degree compared to students in the lowest percentile category. Therefore, socioeconomic status appears to make a larger contribution to whether or not a student obtains a baccalaureate degree (Table 3) than to the type of degree obtained (Table 5).

Model 3 of Table 5 demonstrates the association of science research timing with persistence in biology. The odds of graduation in biology for research participants are about three-and-a-half to five times greater compared to non-participants, with slight differences by initial timing. It appears that participation in research at any point during the undergraduate career is associated with substantially increased odds of persistence in biology. Again, chances of graduation in biology improve with duration of undergraduate research, and, in general, those that participate in research for at least one term have much higher chances of graduation than those that do not participate (Model 4).

A potential problem with predicting the independent association between undergraduate research participation and completion of a biology degree is that students who pursue science research may be more likely to have high GPAs and to be more motivated to obtain a biology degree compared to non-researchers. Students who pursue the biology curriculum longer also have more time and opportunity to become involved in undergraduate research than those who change majors early in their academic careers. Students who remain in the biology curriculum longer may also be more likely to graduate in biology because they have already committed so much time to their major, regardless of whether or not they participate in undergraduate research. These issues are difficult to precisely disentangle given our lack of data on motivation and the non-random assignment of students, but we tried a number of sample restrictions to address these issues.

First, we restricted the sample to students who have persisted in biology majors long enough to complete the Introductory Biology sequence (BIS 1ABC ) (Table 6).[8] Most, but not all, majors in the biological sciences require the entire Introductory Biology course sequence. We use the same variables in Table 6 as in Table 5, which predicts odds of obtaining a biology degree with a broader sample. In all models in Table 6, race/ethnicity, gender, and SES are not significant and the high school achievement coefficients appear slightly smaller in magnitude compared to in Table 5. The indicators for timing and duration of research are also reduced in magnitude, although they retain significance in this restricted sample, with the exception of participation in one term of undergraduate research (Model 4). This is not surprising, in that the sample restriction has resulted in a population that is more focused on obtaining a biology degree. Only 45% of all degree-holders in Table 5 graduated with a degree in biology, compared with 79% of degree-holders in these models, which are restricted to students who have completed the Introduction to Biology yearlong course sequence (See Table 1 for summary statistics of the dependent variables).

In Table 6, we also control for Introductory Biology GPA (Model 5) in order to gain equality in performance within the introductory biology courses. When that variable is added, the duration of research terms are slightly reduced in magnitude, but participation in more than three terms of science research is still associated with an increase of almost 90% in odds of obtaining a biology degree [odds ratio = 1.89].[9]

We also restricted the sample in a manner that makes the group of student researchers more comparable to the non-researchers. We did this by

TABLE 6

Odds of Obtaining a Biology Degree Using Sample Restricted to Introduction to Biology Completers

| | *Model 1:* Social background | *Model 2:* High School achievement | *Model 3:* Research timing | *Model 4:* Duration of research | *Model 5:* Intro. biology GPA |
|---|---|---|---|---|---|
| Female | 0.955 | 0.946 | 0.948 | 0.951 | 0.948 |
| | (0.807–1.103) | (0.793–1.099) | (0.793–1.103) | (0.796–1.106) | (0.789–1.107) |
| Asian | 1.010 | 1.002 | 0.968 | 0.965 | 0.973 |
| | (0.837–1.183) | (0.822–1.181) | (0.792–1.143) | (0.790–1.139) | (0.793–1.152) |
| African American | 0.720 | 1.031 | 0.864 | 0.806 | 0.894 |
| | (0.374–1.067) | (0.522–1.540) | (0.426–1.301) | (0.397–1.215) | (0.431–1.357) |
| Hispanic | 0.817 | 0.967 | 0.907 | 0.882 | 0.971 |
| | (0.600–1.034) | (0.703–1.231) | (0.653–1.160) | (0.636–1.127) | (0.695–1.247) |
| Native American | 0.591 | 0.714 | 0.753 | 0.742 | 0.729 |
| | (0.197–0.986) | (0.232–1.196) | (0.240–1.266) | (0.238–1.245) | (0.220–1.238) |
| Filipino | 1.057 | 1.102 | 1.001 | 1.009 | 1.142 |
| | (0.725–1.390) | (0.748–1.455) | (0.675–1.327) | (0.681–1.338) | (0.762–1.522) |
| EFC 25–49$^{th}$ percentiles | 1.153 | 1.160 | 1.183 | 1.179 | 1.217 |
| | (0.868–1.439) | (0.867–1.453) | (0.881–1.484) | (0.879–1.480) | (0.901–1.534) |
| EFC 50–75$^{th}$ percentiles | 1.210 | 1.205 | 1.262 | 1.259 | 1.303* |
| | (0.909–1.511) | (0.896–1.515) | (0.935–1.589) | (0.933–1.585) | (0.960–1.647) |
| EFC > 75th percentiles | 1.041 | 1.027 | 1.051 | 1.053 | 1.106 |
| | (0.786–1.297) | (0.764–1.290) | (0.780–1.323) | (0.781–1.324) | (0.814–1.398) |
| No financial aid data | 1.017 | 1.049 | 1.081 | 1.086 | 1.055 |
| | (0.769–1.266) | (0.783–1.315) | (0.804–1.358) | (0.809–1.364) | (0.779–1.330) |
| HS GPA 3.67–3.91 | | 1.434*** | 1.400*** | 1.415*** | 1.249* |
| (25–49th percentiles) | | (1.150–1.719) | (1.119–1.681) | (1.132–1.699) | (0.992–1.505) |
| HS GPA 3.92–4.10 | | 1.503*** | 1.467*** | 1.466*** | 1.146 |
| (50–75th percentiles) | | (1.200–1.806) | (1.168–1.766) | (1.168–1.764) | (0.904–1.388) |
| HS GPA > 4.10 | | 2.303*** | 2.183*** | 2.167*** | 1.446** |
| (> 75th percentiles) | | (1.783–2.822) | (1.685–2.681) | (1.673–2.661) | (1.100–1.792) |

TABLE 6 (*Continued*)

Odds of Obtaining a Biology Degree Using Sample Restricted to Introduction to Biology Completers

| | *Model 1:* Social background | *Model 2:* High School achievement | *Model 3:* Research timing | *Model 4:* Duration of research | *Model 5:* Intro. biology GPA |
|---|---|---|---|---|---|
| SATI Math Score | | 1.003*** | 1.002*** | 1.002*** | 1.001 |
| | | (1.001–1.004) | (1.001–1.004) | (1.001–1.004) | (1.000–1.002) |
| SATI Verbal Score | | 0.999 | 0.999 | 0.999 | 0.998*** |
| | | (0.998–1.000) | (0.998–1.000) | (0.998–1.000) | (0.997–0.999) |
| Intro Biology GPA | | | | | 2.324*** |
| | | | | | (2.024–2.623) |
| Initial sci. research during 1st two years | | | 1.989*** (1.294–2.684) | | |
| Initial sci. research during third year | | | 1.669*** (1.176–2.163) | | |
| Initial sci. research after third year | | | 2.232*** (1.820–2.644) | | |
| 1 term of sci. research | | | | 1.212 | 1.082 |
| | | | | (0.974–1.451) | (0.863–1.301) |
| 2–3 terms of sci. research | | | | 2.198*** | 1.873*** |
| | | | | (1.688–2.707) | (1.430–2.316) |
| >3 terms of sci. research | | | | 2.393*** | 1.886*** |
| | | | | (1.691–3.095) | (1.319–2.454) |
| Observations | 3076 | 3076 | 3076 | 3076 | 3076 |
| log likelihood | –1573.376 | –1544.177 | –1512.856 | –1517.631 | –1456.750 |
| Deviance | 3146.751 | 3088.355 | 3025.713 | 3035.262 | 2913.499 |
| BIC' | 73.064 | 54.825 | 16.277 | 25.827 | –87.905 |

*Notes.* Sample is restricted to UC Davis graduates who entered in a biology major and completed the Introduction to Biology sequence (BIS001a, BIS001b, BIS001c).
95% confidence intervals are in parentheses.
$*p < 0.10$; $**p < 0.05$; $***p < 0.01$

considering the raw data for high-achieving students: those with a high school GPA ≥ 4.0 and SAT scores in the 75th and above percentiles (Appendix 1). Among undergraduate research participants in this sample, 76% obtained a biology degree, 20% obtained a non-biology degree, and 4% did not obtain any degree. However, among high-achieving students who did *not* participate in research, only 43% obtained a biology degree while 38% received a non-biology degree and almost 20% did not graduate. The results are similar when matching low-achieving students in that a higher proportion of low-achieving students do not graduate or graduate in a non-biology degree when they do not participate in research compared to when they do (data not shown). However, among these students the numbers in each group become quite small and only 20% of low-achieving students participate in research compared to about 40% of high-achieving students.

*Performance in biology*. Earning a biology degree with a 3.0 or higher cumulative GPA (GPA ≥ 3.0) is a reasonable measure of whether students meet the minimum requirements for admission to graduate or professional school in biology-related professions (Table 7). In Model 1, Asian and underrepresented minority students appear significantly less likely to receive a biology degree with a high undergraduate GPA compared to White students. However, after controlling for high school achievement (Model 2), only Hispanic and Filipino students remain significantly less likely to graduate in biology with a high GPA compared to Whites. Even after adding measures for research experience in Models 3 and 4, the odds of Hispanics and Filipinos graduating with a biology degree and high GPA are only about 44% and 56% [odds ratios = 0.56, 0.44], respectively, that of Whites. Therefore, Hispanics and Filipinos are significantly less likely than comparable Whites to be competitive for graduate or professional school entry, potentially compromising their professional aspirations in biology-related fields.

Women appear slightly more likely to graduate with a high GPA compared to men throughout all of the models. For example, women are about 26% more likely to excel in their science studies than men in Models 3 and 4 [odds ratio = 1.26]. As expected, prior achievement is strongly associated with high grades at graduation in the biology major in Models 2–4. Students in the highest quartile of high school GPA are over 5 times more likely to graduate with a high GPA in the biology major (Models 2–4), compared to students in the lowest quartile. SAT I scores have a modest but significant influence on achievement in the biology major. In Models 2–4, every additional 10 points in math SAT I scores increases the odds of obtaining a high GPA by a factor of 1.006, while every 10-point increase in verbal SAT I scores is associated with an increase in the odds of performing well in biology by 1.004.

TABLE 7

Odds of Obtaining a Biology Degree With a 3.0 Cumulative GPA or Higher

| | *Model 1:* Social background | *Model 2:* High School achievement | *Model 3:* Research timing | *Model 4:* Duration of research |
|---|---|---|---|---|
| Female | 1.210** | 1.247** | 1.258** | 1.260** |
| | (1.038–1.381) | (1.049–1.444) | (1.055–1.461) | (1.057–1.464) |
| Asian | 0.806** | 1.008 | 0.987 | 0.966 |
| | (0.680–0.933) | (0.829–1.186) | (0.809–1.164) | (0.792–1.140) |
| African American | 0.420*** | 1.211 | 0.973 | 0.920 |
| | (0.219–0.621) | (0.562–1.860) | (0.436–1.510) | (0.414–1.426) |
| Hispanic | 0.435*** | 0.673** | 0.567*** | 0.563*** |
| | (0.326–0.545) | (0.484–0.862) | (0.399–0.735) | (0.398–0.729) |
| Native American | 0.483 | 0.676 | 0.667 | 0.647 |
| | (0.131–0.836) | (0.136–1.216) | (0.124–1.211) | (0.125–1.170) |
| Filipino | 0.467*** | 0.519*** | 0.443*** | 0.440*** |
| | (0.338–0.597) | (0.362–0.677) | (0.305–0.580) | (0.303–0.577) |
| EFC 25–49th percentiles | 1.047 | 0.891 | 0.916 | 0.909 |
| | (0.808–1.286) | (0.667–1.115) | (0.682–1.150) | (0.676–1.141) |
| EFC 50–75th percentiles | 1.220 | 0.967 | 1.012 | 1.011 |
| | (0.942–1.499) | (0.722–1.213) | (0.751–1.273) | (0.750–1.272) |
| EFC > 75th percentiles | 1.303* | 0.939 | 0.964 | 0.972 |
| | (1.001–1.605) | (0.695–1.183) | (0.711–1.218) | (0.716–1.228) |
| No financial aid data | 1.172 | 1.037 | 1.058 | 1.082 |
| | (0.903–1.442) | (0.772–1.302) | (0.783–1.332) | (0.802–1.362) |
| HS GPA 3.69-3.94 (25–49th percentiles) | | 1.639*** (1.312–1.966) | 1.634*** (1.302–1.965) | 1.663*** (1.324–2.001) |
| HS GPA 3.95-4.12 (50–75th percentiles) | | 2.952*** (2.347–3.557) | 3.014*** (2.385–3.644) | 3.015*** (2.385–3.645) |
| HS GPA > 4.12 (> 75th percentiles) | | 5.290*** (4.086–6.494) | 5.323*** (4.091–6.556) | 5.233*** (4.022–6.444) |
| SATI Math Score | | 1.006*** | 1.006*** | 1.006*** |
| | | (1.005–1.007) | (1.005–1.007) | (1.004–1.007) |
| SATI Verbal Score | | 1.004*** | 1.004*** | 1.004*** |
| | | (1.003–1.005) | (1.003–1.005) | (1.003–1.005) |
| Initial sci. research during 1st two years | | | 3.417*** (2.243–4.591) | |
| Initial sci. research during third year | | | 2.177*** (1.555–2.799) | |
| Initial sci. research after third year | | | 2.052*** (1.708–2.396) | |
| 1 term of sci. research | | | | 1.618*** |
| | | | | (1.288–1.948) |
| 2–3 terms of sci. research | | | | 1.886*** |
| | | | | (1.508–2.263) |
| > 3 terms of sci. research | | | | 3.593*** |
| | | | | (2.639–4.548) |
| Observations | 2532 | 2532 | 2532 | 2532 |
| log likelihood | –1676.662 | –1480.842 | –1439.745 | –1438.804 |
| Deviance | 3353.323 | 2961.685 | 2879.490 | 2877.608 |
| BIC' | 11.613 | –340.842 | –399.526 | –401.408 |

*Notes.* Sample is restricted to UC Davis graduates with a major in biology.
95% confidence intervals are in parentheses.
$*p < 0.10$; $**p < 0.05$; $***p < 0.01$

In Models 3 and 4, science research participation is also strongly associated with performance in biology. Participating in science research during the first two years or for more than three terms is associated with about a 240% increase in a student's odds of graduation in biology with a GPA competitive for admission to graduate or professional school [odds ratio = 3.42, 3.59, respectively]. Students who participate in science research during or after their third year are about twice as likely to graduate in biology with a high GPA compared to non-participants [odds ratio = 2.17, 2.05], while those who participated in research for one to three terms are 60–90% more likely to graduate in biology with a GPA sufficient for pursuit of graduate study [odds ratio = 1.62 and 1.89].

## *Discussion and Conclusion*

Our study examines the association between undergraduate research participation and college retention and persistence and performance in biology for students who entered UC Davis with an expressed interest in the biological sciences. Despite differences among these students in prior achievement and demographic characteristics, undergraduate research is positively associated with odds of obtaining a baccalaureate degree, persisting in biology, and performing well in biology. We found no significant differences between underrepresented minorities and Asian and White students in the association between research participation and graduation outcomes, but non-Filipino underrepresented minorities had lower predicted probabilities of graduation regardless of undergraduate research status. Hispanic and African American students also had the largest gap between those that did research and those that did not in their probability of obtaining a biology degree. Since underrepresented minorities have higher rates of attrition and lower levels of academic performance to begin with, research participation may particularly help prepare underrepresented minorities for graduate education and careers in the sciences, while providing a form of institutional integration into a competitive major at a large university.

When we consider the timing and duration of research and graduation in any major, participation in research during or after the third year or for one or more terms is strongly associated with college retention. In models predicting retention and performance in biology, participation in research during the first two years is almost as strong or slightly stronger in magnitude compared to participation in research during later stages in college. We tried to test interaction terms between the timing of research and racial/ethnic status, but since the cell sizes became so small, these terms lacked statistical significance. Although we did not find statistical differences by race/ethnicity, initiating undergraduate research early on may be particularly beneficial for underrepresented minorities by helping them to academically and socially integrate, find support systems, and secure a sense of belonging when students take "weeding out" courses in the sciences and face the harsh transition to college (Hurtado et al., 2007; Seymour & Hewitt, 1997). For all students, and possibly students of other majors, participation in research early on could positively influence retention since past research finds that involvement in formal campus activities during the first two years leads to greater academic success, college satisfaction levels, and retention rates among students of different racial/ethnic backgrounds and majors (Fischer, 2007).

Longevity in research is also highly associated with persistence and performance in biology. Extended periods of undergraduate research participation may be important because of the increased levels of faculty and peer contact and longer time to gain confidence and identification in the institution and major, which past research identifies as important for college retention (Pascarella, 1980; Pascarella & Terenzini, 1977, 1979; Tinto, 1993). However, those that remain longer in research could also be more likely to remain in the major because they are more motivated to begin with or because they have already committed a great deal of time to the major. More precisely, do students who are more motivated seek out research experiences, or does the research experience motivate students to continue in science? For example, we found that initial science research participation during the first two years has a slightly stronger association with performance in biology compared to participation during the third year. This may be because research participation motivates students to perform well or because academically successful students are more likely to select research during their first two years. Even though we control for prior academic achievement, without random assortment of students into research experiences versus a non-research control group, we cannot completely address this selection bias issue.

We have, however, tested the statistical association between undergraduate research and academic success by using highly conservative models. In models not shown predicting the odds of college graduation, we tried restricting the sample to high-achieving students and to students who remained at UC Davis after their first two years, and we controlled for number of terms enrolled at UC Davis. We also restricted our analyses on persistence and performance in biology to students who had completed various levels of biology courses (sample restriced to Introduction to Biology completers was shown in Table 6), and we matched high-achieving students with and without research participation (Appendix 1). In all of these models, despite the severe sample restrictions, we still found a positive association between research participation and graduation outcomes. In particular, we found that participating in as little as one to three terms of research and initiating that research during the first two years has strong positive associations with graduation outcomes, which provides some indication that undergraduate research may be beneficial even among those who are not highly committed to the major to begin with. However, selection into undergraduate research programs may include more complex factors than our data can address, such as involvement in pre-professional or departmental clubs or frequent faculty-student interactions prior to initiation of undergraduate research participation, which a recent study finds to be important in predicting first-year participation in health science research (Hurtado et al., 2008). We encourage future studies to examine issues of motivation and selection, as well as timing and duration of research, among undergraduate research participants more closely.

This study has a number of other limitations. First of all, our study is of one large, selective research institution; therefore, it is mainly representative of similar institutions with fairly high academic levels among incoming freshman. Because of this, our estimates of the positive association between undergraduate research participation and graduation outcomes may be overly conservative for national trends. The associations that we find may be even stronger at less-selective institutions, where students are more disadvantaged in terms of achievement levels, academic support systems, and institutional prestige.

Second, while the transcript data we used are largely complete and accurate, the research course listings (99 and 199) do not capture all of the research activity available to students. Working in a technical capacity for pay is another option. While we know that working for pay is not widely available to the general student body, our inability to capture that experience means that our estimate of research participation is slightly low. However, in a 2002 survey of UC Davis baccalaureate degree recipients, 47% of graduates reported having worked on a creative or research project in any major with a faculty member (Barlow, 2004), which roughly corresponds with our estimate of 45% of all students in Table 1. Another factor we cannot measure is variation in quality of the research experience, including quality and quantity of faculty contact, the developmental nature of the work, and the level of skills acquired. Due to our lack of more in-depth data, we cannot tell how specific components of undergraduate research may affect groups differently.

Qualitative studies have identified how the nature and quality of the undergraduate research experience might help students to persist in college and in the biological sciences (Hunter et al., 2007; Kardash, 2000; Lopatto, 2004; Seymour et al., 2004). Students in these studies cited the benefits of personal-professional gains most frequently, a category that included increased confidence and establishing collegial, working relationships with faculty advisors and peers. Other research suggests that these types of relationships forged in the undergraduate research environment result in greater numbers of faculty recommendations and increased contact with faculty after graduation, as well as an increased likelihood of pursuing graduate education and being involved in future research (Hathaway et al., 2002).

At UC Davis, BUSP provides an avenue for minority and disadvantaged students to gain increased research experience along with additional instruction, mentoring, and support (Villarejo & Barlow, 2007). Surveys and interviews of high-achieving BUSP alumni address aspects of the research experience that alumni perceive as valuable during their time at UC Davis and along their career path. In the surveys, BUSP alumni highlighted the importance of the research experience for building relationships with faculty and other members of the science community. While almost all (97%) of the 201 survey respondents reported having received advice or encouragement from faculty or staff at UC Davis, alumni who participated in research reported using a wider array of mentoring resources. They frequently cited members of their research unit, such as their research director, laboratory technicians, and postdoctoral scientists as sources of advice and encouragement (Villarejo, Barlow, Kogan, Veazey, & Sweeney, 2008).

BUSP alumni survey responses also suggest ways that undergraduate research might influence retention and performance in biology majors. Forty-one percent of respondents who performed undergraduate research said that the experience had influenced their choice of college major. For example, one of the alumni stated, “My research experience helped me gain a deeper understanding of some scientific topics, but most importantly, it peaked [sic] my interest in biology. I wanted to understand what was being done in the lab, so I chose a Biological sciences [general biology] major.” Additionally, over 81% of survey respondents who graduated in biology reported that undergraduate research contributed “somewhat” or “a great deal” to their understanding of science coursework. One of the survey respondents wrote, “My major was Biochemistry and therefore, undergrad[uate] research made understanding molecular, cellular, and biochemical concepts easier. Hands on experience greatly exceeds textbook material” (Villarejo et al., 2008). Additional analysis of our qualitative data regarding the experiences of students who have participated in undergraduate research will enhance our understanding of the aspects of undergraduate research that are associated with graduation outcomes.

In conclusion, we suggest that greater availability of undergraduate research experiences might counter some of the high attrition rates from science majors and contribute to attracting a diverse workforce to science careers. In particular, we find that introducing students to undergraduate research early on and for an extended period of time are beneficial for the retention and performance of all students, but that underrepresented minorities may have the most to gain from such strategies. Support for undergraduate research has come from institutions and federal and private agencies, both as a means to improve pedagogical practices in the sciences and to enhance the pool of minority researchers and scientists (National Science Foundation, 2003, 2004). Given the pedagogical and policy implications, it is clear that more research using sophisticated analyses and data is needed to improve our understanding of the role of undergraduate research in persistence and performance in the sciences. We believe that this study is a step in that direction, and we hope that it will stimulate future research on this subject.

APPENDIX 1

Research Participation and Graduation Outcomes Percentages Among High Achievers

| | Non-biology degree | | Biology degree | | No degree | | Total | |
|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % |
| Science research | 33 | 20% | 124 | 76% | 6 | 4% | 163 | 39% |
| No research | 96 | 38% | 110 | 43% | 49 | 19% | 255 | 61% |
| Total | 129 | 31% | 234 | 56% | 55 | 13% | 418 | 100% |

*Note.* Sample is restricted to students with a High School GPA greater than 4.0 & SAT math & verbal scores in the 75th percentile or above.

## *Notes*

[1]This percentage is a rate, based on the number of baccalaureate degrees conferred per 100 population, disaggregated by race/ethnicity.

[2]Students who entered UC Davis their first year in majors in the College of Biological Sciences along with students with majors in the College of Agriculture and Environmental Sciences, which included a substantive biology curriculum, were included in the sample.

[3]We also retrieved student-reported parental education data from SARI. In additional analyses controlling for parental education (data not shown), the coefficients showed little change, except parental education slightly mediated the effect of Expected Family Contribution on graduation outcomes. We present models using only EFC as a measure of socioeconomic status to retain parsimony and because EFC is a more accurate measure; EFC is calculated from federally-verifiable sources, including the Free Application for Federal Student Aid and income tax forms. We cross-tabulated the parental education measures with the EFC measures and they matched in the expected manner.

[4]High school GPA is calculated by SARI using only the academic courses (California A-F requirements) taken in the 10th and 11th grades; extra credit for honors and AP courses (which account for GPAs above 4.0) are capped at eight semesters. We also evaluated models in which we entered GPA as a linear measure. Substantive results were no different, but the linear measure posed problems once we restricted the sample to biology graduates due to the uneven distribution of high school GPA among the selective sample. BIC model fit statistics also suggested that the models using quartile variables were slightly preferred, especially in the restricted samples.

[5]"Special Study" courses are defined in the course catalog as "arranged for an individual student who shares with an instructor an academic interest that cannot be accommodated within the formal course structure" (Office of the University Registrar, 1999).

[6]About 54% of underrepresented minorities who participate in science research are a part of BUSP.

[7]In additional analyses not shown, we controlled for total number of terms registered at UC Davis to account for the possible relationship between length of enrollment and research participation (students enrolled for a greater period of time have more opportunity to participate in undergraduate research). Controlling for number of terms slightly reduced the magnitude of the participation in research terms, but it did not change significance levels. However, number of terms is not completely independent of the dependent variable. Students with a low number of registered terms cannot possibly meet all of their requirements to graduate. We also ran the models predicting graduation restricted to students who remained after their second and third years and to students with a high school GPA of 4.0 or greater. In these models not shown, the coefficients showed little changes and the research participation terms remained significant, although they were slightly smaller in magnitude.

[8]The three-quarter Introductory Biology course sequence was designed to be taken by the end of the sophomore year. However, many students, especially those who are premedical or interested in animal biology, postpone taking the final course, Plant Biology, until their last year. Therefore, students take components of the course sequence at various points in time during their college career.

[9]We also restricted models predicting persistence in biology among degree holders to those who completed the Upper Division Biology sequence (BIS 101–104, data not shown). In these models, all individual background variables lost significance, except Hispanic students were significantly less likely to graduate in biology compared to Whites. Students who initially participated in science research after the third year or who participated in more than three terms remained significantly more likely to persist in biology compared to non-researchers. In these models (not shown), we controlled for Upper Division Biology GPA and the coefficients showed little changes.

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