MAJORS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS: GENDER AND ETHNIC DIFFERENCES IN PERSISTENCE AND GRADUATION*

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This article discussed enrollment, persistence, and graduation patterns of undergraduate college students (including racial-ethnic and gender groups) in the disciplines of science, technology, mathematics, and engineering (STEM). The data indicated that women and racial-ethnic minorities (except Asian-Americans) were underrepresented in STEM disciplines and that a significant majority of freshman STEM majors either dropped out or switched to non-STEM disciplines. The persistence and graduation rates in STEM disciplines among women and underrepresented minorities were also lower. Significant factors related to persistence and graduation of STEM majors included institutional variables (such as size and control) and student variables (such as race and academic ability).

INTRODUCTION

Scientific knowledge and innovations have been linked to the nation's comparative advantage in the global economy in the last forty-five years since *Sputnik*. If college students in the fields of science, technology, engineering, and mathematics (STEM) are the essential conduits to bringing about new and innovative scientific knowledge necessary for the nation's future, the pipeline issue of student entry into STEM disciplines in higher education and issues related to student persistence and graduation must take paramount importance. Adding to this complexity is the human resource consideration, which acts a reminder that all college students—women and racial-ethnic minorities included—must be fully encouraged to take part in order to benefit the entire nation.

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BACKGROUND

The progress report on the pipeline issue is still somewhat inconclusive. Perhaps the two most comprehensive and latest reports on the status of STEM majors in higher education are those released by the National Center for Education Statistics (Huang, 2000) and the Center for Institutional Data Exchange and Analysis (C-IDEA) located at the University of Oklahoma (Smith, 2001). Both reports offer some interesting contrasts and comparisons.

The 2000 NCES report indicated that the enrollment patterns in STEM fields from 1989 to 1994 among all racial-ethnic groups (excluding Asian-Americans) had narrowed—the percentage of STEM majors represented by all ethnic groups (including whites) was about 17%. The Asian-American group's representation was about 21%. Pertaining to gender, the report found a persistent gap in STEM enrollments during the five-year period of the study: the percent difference was about 10% in 1989 and widened slightly to 14% in 1994. Specifically, the women's and men's participation rates in STEM majors were 10% and 24% respectively (Huang, et al., 2000).

Along a similar vein, C-IDEA found that first-time freshman enrollment in STEM disciplines increased by 25% from 1993 to 1999 (this in contrast to an increase of 20% from 1992 to 1998). However, the report found that women and ethnic minorities (with the exception of Asian Americans) were still underrepresented in the STEM disciplines during that same time period. Specifically, women represented 38% of all first-time STEM freshmen compared to 62% who were men. By minority status, 9% of all first-time STEM freshmen were African-Americans, 7% were Hispanics, and 1% were Native Americans (in contrast to 83% of Whites and Asian-Americans). In addition, the report indicated that more women and minorities in STEM disciplines were enrolled in less selective institutions (categorized by average standardized test scores): 43% of all STEM minority students and 43% of women were enrolled in these institutions (Smith, 2001).

Once students are in college, their persistence and graduation in their STEM disciplines is the second part of the equation. Using about 900 students from the *Beginning Postsecondary*

Longitudinal Study database, the 2000 NCES study reported some interesting differences among the racial-ethnic groups. Specifically, only 27% of underrepresented minority students graduated in their STEM disciplines in five years compared to 46% of non-minority students and Asian-Americans. This was a statistically significant difference. Among those students who were still persisting in their STEM disciplines after five years, about 21% of them were underrepresented minorities and 15% were non-minorities and Asian-Americans. Among those who switched to other non-STEM majors without finishing their STEM degrees, 31% were underrepresented minorities and 14% non-minorities and Asian-Americans. The study also focused on those STEM students who dropped out of higher education without completing any degree program. Among these students, there was no difference by racial-ethnic groupings—about 22% of both non-minority and minority students dropped out completely (Huang et al., 2000). Most of the comparisons were not tested for significance due to low cell frequencies.

Pertaining to differences between male and female STEM students, the 2000 NCES study revealed that significantly more women than men graduated in their STEM disciplines (49% compared to 40%). Among the persisters (those who remained in their STEM disciplines after five years), 13% were women and 18% men (no test of significance was performed due to sample size problem). Among those who switched to other non-STEM disciplines, 12% were women and 19% men (again no test of significance was performed). Among those who dropped out completely, about 24% were women and 22% men—this was a statistically significant difference (Huang et al., 2000).

Pertaining to the persistence of STEM majors, the 2001 C-IDEA study reported that close to half of the 1993-94 freshmen STEM majors left their majors before reaching their junior year. Over a period of six years, an overwhelming majority (59%) of all STEM majors either dropped out of college or transferred to non-STEM disciplines. Year-to-year persistence data showed that of those who left their STEM disciplines, 31% left in the first year, 16% in the second year, and 12% in the third and subsequent years (Smith, 2001).

By racial-ethnic groups, the proportion of minority students who continued in their STEM majors during the second year was lower than of non-minority students (65% compared to 69%). The general persistence rates (regardless of whether they switched majors or remained in their STEM disciplines) were 76% for minorities and 82% for non-minorities. By gender, the general persistence rate among women was 80% compared to 82% for men. The difference in discipline-based persistence (that is, those who continued in their STEM majors) was slightly higher for males (69%) than for females (66%).

Pertaining to graduation rates, C-IDEA reported that 56% of the 1993-94 STEM cohorts graduated in six years; 38% graduated from an STEM discipline, and an additional 18% graduated from non-STEM disciplines. C-IDEA also noted that at the end of the six-year tracking period, between 3-5% of the STEM cohorts were still continuing their enrollment to the seventh year. As a result, C-IDEA predicted that many of these students would complete their degrees, increasing the final graduation rate of the 1993-94 STEM cohorts to 62% (Smith, 2001).

By racial-ethnic groups, C-IDEA was reporting that the proportion of minority students who graduated with their STEM majors in six years was significantly different from that of non-minority students (23% compared to 41%). The general graduation rates (regardless of whether they switched majors or remained in their STEM disciplines) were 39% for minorities and 60% for non-minorities. By gender, the general graduation rate among women was 60% compared to 54% for men. The difference in discipline-based graduation (that is, those who graduated with their STEM degrees) was slightly higher for males (39%) than for females (35%) (Smith, 2001).

If there are differences in the persistence and graduation rates among the genders and racial-ethnic groups, what would help explain these differences? This is the third part of equation dealing with the phenomena of persistence and graduation.

The research and theories related to explanations of persistence and graduation among the general college population are comprehensive. Unfortunately, there is relatively little known about persistence and graduation pertaining to STEM majors in specific. The few exceptions were studies conducted by Hill (1996), Huang (2000), and Sax (2001), but the knowledge base is far

from complete. In order to gain some preliminary knowledge about the potential correlates of persistence and graduation of STEM majors, the correlates of persistence and graduation related to the general college population can be identified and tested to see if they are also pertinent to STEM majors.

Among the variables identified as potential correlates of persistence and graduation of the general college population (and potentially of STEM majors) included institutional size, type (Carnegie classifications), or control (public-private) (Huang, 2001; Smith, 2001; US Congress, 1992); institutional selectivity (Smart, 1986; Tinto, 1980); standardized test scores (Griffiths et al., 1992; Kroc et al., 1995; Saupe et al., 1999); academic ability of students or high school performance (Astin, 1978, 1985; Saupe, 1988; Saupe et al., 1999; Smith, 2001); standardized test scores (Griffiths et al., 1992; Kroc et al., 1995; Saupe et al., 1999); faculty-student interaction or class size (US Congress, 1992); diversified student body and racial climate (Hurtado et al., 1998; Seymour & Hewitt, 1997); age of students (Saupe et al., 1999); better fit in values and culture with underrepresented groups vis-à-vis performance and collaboration (Seymour & Hewitt, 1997); faculty responsiveness and teaching (Seymour & Hewitt, 1997); student involvement and effort (Astin, 1985; Pascarella, 1985); student academic and social integration (Murguia et al., 1991; Tinto, 1986); availability of financial aid (DuBrock, 2000; Friedman & Kay, 1990; Huang, 2001; Seymour & Hewitt, 1997); enrichment (not remedial) programs (Seymour & Hewitt, 1997); parents' college education and their financial support (Huang, 2001); and higher confidence and aspirations for advanced STEM studies (Huang, 2001).

The fact that studies on factors related to persistence and graduation of STEM majors are few and inconclusive lend itself well to the need for this particular study. To be sure, the purpose of the study was to examine the factors related to persistence and graduation of STEM undergraduate students who remained in their STEM disciplines. The study had several important advantages. The first was that the study was multi-institutional, covering 175 institutions nationwide. The second was that the study explored quite a comprehensive list of variables potentially linked to persistence and graduation.

METHODOLOGY

Based on the literature review and the discussion above, the following variables were included in the study:

1. Persistence (C2YR): Continuation rates among STEM majors to the second year.
2. Graduation (GRAD6): Graduation rates among STEM majors within six years of enrollment.
3. Race (RACE): 0=white and others; 1=minorities (African-American, Hispanic, Native American)
4. Gender (GENDER): 0=male and 1=female
5. Standardized Scores (SDTEST): Mean standardized test scores of STEM majors (ACT scores were converted to SAT equivalence using a concordance table. The equivalent SELECT is computed based on ACT or SAT scores (0=ACT>21 or SAT>990; 1=ACT<21 or SAT<990)
6. Part-Time Enrollment (PART): Percentage of undergraduates who are attending college part-time.
7. Control (CONTROL): 0=private; 1=public
8. Carnegie: 0=Research I & II, Doctoral I & II; 1=Masters I & II, Bachelor's I & II, and others.
9. Institutional size (TENROLL): Total graduate and undergraduate enrollment.
10. Percent Degree-Seeking (DEGREE): Percent of undergraduate students who are degree-seeking.
11. First-semester GPA (FGPA): Grade-point-average is calculated for all undergraduate students, regardless of majors.
12. Percent Poor GPA (POORG): Percent of all students with first-semester grade-point-average below 2.0
13. Percent Age (AGE): Percent of undergraduate students who are 24 years or older.

14. Percent Housing (HOUSE): Percent of undergraduate students who lived in university housing.
15. Percent Minority (MINOR): Percent of underrepresented undergraduate minorities on campus.
16. Percent High School Rank (HS10): Percent of undergraduate students who graduated in the top 10% of their high school classes.
17. Percent STEM Minority (SMINOR): Percent of underrepresented minority STEM majors.
18. Percent Financial Aid (FINAID): Percent of all undergraduate students receiving all forms of financial aid in 2000-2001.
19. Student-faculty ratio (SFRATIO): Ratio of the number of students to faculty in 2000-2001.
20. Percent Small Classes (SMALLC): Percent of classes with fewer than 20 students in 2000-2001.

Data on these variables came primarily from the only known national retention STEM databases compiled by the Center for Institutional Data Exchange and Analysis (C-IDEA) (Smith, 1999, 2001). The Center, with funding from National Science Foundation, is in its second year of operation. From 120 participating institutions during its first year, the number is now 175. The sample consisted of public and private institutions nationwide, ranging from doctoral to baccalaureate institutions. Data on the last three variables came from the *US News and Report* (2002). Despite lingering controversies associated with institutional and program rankings from this publisher and others, the data for the three variables were judged to be appropriate since they were not collected based on subjective evaluations.

C-IDEA maintained three databases on STEM majors. The first database contained data on students of all majors; the second on those who started out as STEM majors, switched to other majors and persisted, transferred, or dropped out; and the third on those who started as STEM majors, remained, and graduated as STEM majors. Only the third database was used since it was the most relevant to the study's research question. Each database contained information on at least

six cohorts, beginning with 1993 to 1999. The 1993-94 cohort year was chosen since this group had stayed the longest in higher education, and data on this group were the most complete.

Stepwise multiple regression was used to estimate the relationships between the dependent variables (persistence and graduation) and the eighteen independent variables. Persistence was measured by the proportion of the 1993-94 student cohort who continued to the second year, and graduation was measured by the graduation rate of the same students over a six-year period. Three subgroup analyses were performed for each of the two dependent variables. The first group consisted of all students; the second consisted of racial-ethnic cohorts; and the third group consisted of gender cohorts. Sub-group analyses were necessary since the data on race and gender were kept separately. The racial-ethnic cohort analysis was carried out by adding the RACE variable (0=non-minority; 1=minority) to all the existing variables. The minority group included Hispanics, African-Americans, and Native Americans. The non-minority group included Whites, Asian Americans, resident aliens, and others (including who did not identify a race). Likewise, the gender cohort analysis was administered by adding the GENDER variable (0=male; 1=female) to the list of existing variables. In addition, standardized test scores could not be used in the race-ethnic analysis because the data on test scores were not reported. As an alternative, institutional selectivity was used: a value of "0" denoted a "highly selective" institution with an average ACT score higher than 21 or SAT higher than 990; and a value of "1" denoted a "less selective" institution with standardized scores lower than those just mentioned.

FINDINGS

Persistence

The only significant predictor of second-year persistence among all STEM students, regardless of their race or gender, was their standardized scores—the R-Square was 13% (Table 1). The higher the standardized test scores, the higher was the rate of persistence among the students. In the race-ethnic cohort analysis, the significant predictors were institutional selectivity, institutional control (public/private), student-faculty ratio, and institutional size (R-square was

23%). Standardized test scores and student-faculty ratio had negative coefficients, and race had no bearing on persistence. In the gender cohort analysis, standardized test scores and institutional type (research/doctoral-granting or not) were significant predictors (R-square was 17%). Gender was not a significant factor related to persistence (Table 1).

[INSERT TABLE 1 ABOUT HERE]

A simultaneous examination of all three sub-groups revealed some similarities and differences. First, standardized test scores as a variable was a common link—better scores or better institutional selectivity enhanced the persistence of all students, all race-ethnic groups, and both genders. Some of the differences, on the other hand, included institutional type (which was important to the gender cohorts only), and institutional control (which was important to the race/ethnic cohorts only). Perhaps the most important finding was that race and gender had no bearing on persistence (Table 1).

Graduation

The significant predictors of graduation for all STEM majors, regardless of race or gender, were the percent of part-time undergraduates, the percent of students with grade-point-average less than 2.0, and standardized test scores—the R-square was 51% (Table 2). In the race/ethnic cohort analysis, the significant predictors were student-faculty ratio, race, institutional selectivity, first semester grade-point-average, and percent of part-time undergraduates (R-square was 48%). Supplemental information revealed that the mean graduation rates of non-minority and minority were 32.9% and 24.5% respectively ($f=22.145$, $df=300$, $p<.001$). The mean graduation rate for all students was 29.1%. In the gender cohort analysis, standardized test scores, first semester grade-point-average, and the percent of part-time undergraduates (R-square was 46%). Gender was not a factor (Table 2).

[INSERT TABLE 2 ABOUT HERE]

A simultaneous examination of all three sub-groups revealed these similarities and differences. Among the similarities were standardized test scores and the percent of part-time undergraduates. In addition, first-semester grade-point-average was important to both the racial-ethnic and gender cohorts but not to all students as a whole. The differences, on the hand, were student-faculty ratio (which was important to the racial-ethnic cohorts only) and the percent of students with grade-point-average less than 2.0 (which was relevant to all students). Perhaps the most significant finding was that race was a factor related to graduation. However, gender was not related to graduation (Table 2).

DISCUSSIONS AND IMPLICATIONS

While the need for the nation to be technologically advanced is clear, the strategies for preparing, retaining, and graduating more college students in STEM disciplines from all ethnic and gender groups remain complicated. Although it is true that freshman STEM majors have indeed grown in numbers in the last decade or so, women and ethnic minorities (with the exception of Asian Americans) are still underrepresented in STEM disciplines. Compounding the problem are the lower persistence and graduation rates among underrepresented minorities and women. What are the possible resolutions?

Perhaps the first issue to be addressed should be the academic preparedness of potential college students. There is evidence that high school students are taking more science and mathematics courses (and also more advanced ones) and that ethnic and gender gaps in both enrollment and performance in these courses have narrowed in the last 30 years (Basinger, 2000). But unfortunately, according to Basinger, that progress appeared to have stalled since 1992. Nevertheless, the narrowing of the gap in national mathematics test scores between males and females in high school is encouraging; so is the narrowing of the gap in performance between non-

minority and minority students (Basinger, 2000; Huang et al., 2000), but there are still significant issues yet to be resolved.

If students are taking more science and mathematics courses in high school, does it mean that more students will be attending college declaring themselves as STEM majors? The preliminary news is encouraging. Hilton and Lee (1988), for example, examined the interests of high school students and discovered that from 1972 to 1982, the proportion of high school African-Americans who expressed the intent of becoming STEM majors in college nearly doubled. The authors found a similar trend among female high school seniors. Unfortunately, intent did not necessary translate into real behavior, as the author pointed out. In fact, the author claimed that the transition from high school to college was a bigger problem than the net loss once they are in college.

What really happened to STEM students once they are in college? The evidence here has not been encouraging. Returning to the points made earlier, women and ethnic minorities (except Asian-Americans) were still underrepresented in STEM disciplines. To make matters worse, a significant proportion (close to 60%) of all STEM majors, regardless of gender or ethnicity, dropped out of college or transferred to non-STEM disciplines. This figure should merit concern. Of those who remained, only about a third would ultimately graduate in six years with degrees in STEM disciplines.

Among those who remained in their STEM disciplines (the focus of this study), only a few variables were related to their persistence and ultimate graduation. The variables found to be related were standardized test scores or institutional selectivity, institutional control, institutional size, institutional type (Carnegie classifications), student-faculty ratio, the percent of part-time undergraduates, the percent of students with grade-point-average less than 2.0, and first-semester grade-point-average. These findings were consistent with those reported by previous researchers (e.g. Astin, 1985; Huang et al., 2000; Saupe et al., 1999). The most important finding was that gender was not related to both persistence and graduation but race was a significant factor related to graduation.

Perhaps more telling were the variables that did not turn out to be significant in this study. For example, the percent of underrepresented minorities and the percent of underrepresented STEM majors on campus (both student diversity variables) were expected to be significant factors related to persistence or graduation, but both turned out not to be the case, not even to minority students. Also expected to be important correlates were small class sizes (arguably important to students in STEM disciplines) and the availability of student financial aid, but they were not significant either. Neither were high school academic ability, the diversity of the student body by age, nor whether the students lived in university housing. The preliminary implication (although definitely not conclusive) appears to be that student diversity and culture (by ethnic, gender, and age), the closeness of faculty and students (potentially brought about by smaller classes), financial aid, and some elements of social integration on campus (such as those associated with on-campus living) are not significant factors related to persistence and graduation. It is important in future research to investigate these further.

CONCLUSIONS

Although this study discussed and provided some important national benchmark information about the persistence and graduation rates of STEM majors and the conditional effects certain student and institutional characteristics can have on persistence and graduation, it has limitations. Perhaps the most important limitation was that the study did not consider direct variables related to the student collegiate experiences, particularly those pertaining to their level of involvement, engagement, and integration on campus. The study also did not consider the type and extent of retention programs that might have made a difference in reducing the magnitude of student dropout. Also not explored were some potential experiences uniquely associated with women and minorities in STEM disciplines, such as the varying value placed on personal success and satisfaction. On this point, Seymour and Hewitt (1997) argue that since minorities and women are likely to favor or value people and teamwork over individual success or performance normally associated with the STEM culture, this conflict can lead to student departure. Unfortunately, this

issue was not explored in this study. Nevertheless, this issue remains an important one, and perhaps a potential answer may lie in this statement made by Barber (1995, p. 232): "Transforming the culture of science is the key to narrowing the science and engineering gap." In the author's assertion, intervention strategies can be successful if they are focused on widening the cultural norms and expectations of the profession rather than on successful assimilation of students into the existing culture.

The fact that the persistence and graduation rates of women and ethnic minorities are still problematic does suggest that much more can be done to create a more supportive institutional, social, cultural, racial, student, and faculty cultures that can challenge students to do their best work, promote a better sense of belonging and meaning, and encourage them to persist and ultimately graduate with their degrees. Of course no plan can be complete unless it includes strategies to encourage greater participation in science and mathematics classes in high school or even earlier, particularly among minorities and female students, and to persuade them to pursue degrees in STEM disciplines in college.

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TABLE 1: Regression Results for Predicting Second-Year Persistence STEM Students Who Remained in their Disciplines

	All Students			Race-Ethnic Cohorts			Gender Cohorts		
Variables	Unstd. B	Std. B	p	Unstd. B	Std. B	p	Unstd. B	Std. B	p
N	173			325			343		
R	.366			.416			.421		
R-Square	.134			.227			.177		
(Constant)	151.711		0.445	890.938		0.000	213.154		0.157
Race									
Std. Score	0.449	0.366	0.020	-76.093[1]	-0.210[1]	0.034[1]	0.408	0.306	0.004
Gender									
% part-time									
Control				177.103	0.415	0.001			
Carnegie							-127.272	-0.242	0.023
Total enrollment				0.004	0.227	0.039			
% degree seekers									
First sem gpa									
% gpa<2.0									
% age 24>									
% univ. housing									
% minorities									
% top10% hs rank									
% minority STEM									
% financial aid									
Stud-fac ratio				-26.384	-0.468	0.000			
% classes 20<									
	Predictors: (Constant), SDTEST			Predictors: (Constant), SELECT, CONTROL, SFRATIO, TENROLL			Predictors: (Constant), SDTEST, CARNEGIE		

[1]selectivity index was used (0=highly selective; 1=less selective) instead of standardized test scores

TABLE 2: Regression Results for Predicting Six-Year Graduation STEM Students Who Remained in their Disciplines

	All Students			Race-Ethnic Cohorts			Gender Cohorts		
Variables	Unstd. B	Std. B	p	Unstd. B	Std. B	p	Unstd. B	Std. B	p
N	169			302			343		
R	.714			.689			.674		
R-Square	.510			.475			.455		
(Constant)	129.172		0.421	347.845		0.033	-682.151		0.000
Race				-113.816	-0.403	0.000			
Std. Score	0.390	0.353	0.007	-74.990[1]	-0.229[1]	0.010[1]	0.429	0.379	0.000
Gender									
% part-time	-3.138	-0.323	0.013	-2.370	-0.186	0.035	-2.815	-0.282	0.002
Control									
Carnegie									
Total enrollment									
%degree seekers									
First sem gpa				1.244	0.207	0.013	2.300	0.387	0.000
% gpa<2.0	-7.531	-0.408	0.001						
% age 24>									
% univ. housing									
% minorities									
% top10% hs									
% minority STEM									
% financial aid									
Stud-fac ratio				-15.669	-0.309	0.000			
% classes 20<									
	Predictors: (Constant), PT, POORG, SDTEST			Predictors: (Constant), SFRATIO, RACE, SELECT, FGPA, PT			Predictors: (Constant), SAT, FGPA, PT		

[1]selectivity index was used (0=highly selective; 1=less selective) instead of standardized test scores