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Underrepresented Undergraduates' Persistence in STEM Fields

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Abstract

This study uses longitudinal data from three, large public research universities in the Midwest to better understand the educational outcomes of women and minority students as they move through the STEM pipeline. Descriptive statistics and conditional probabilities analysis offer insight into differential rates of persistence and degree attainment in the STEM fields.

Introduction

Although the number of women and minorities (hereafter, “underrepresented”) students in the science, technology, engineering and mathematics (STEM) pipeline has slowly increased over the past three decades, disparities still exists between well-represented (defined in this study as White and Asian men) and underrepresented populations in these fields (Oakes, 1990; Stake & Mares, 2001). The factors that contribute to the challenges of access and completion, however, continue to confound educators, researchers, college administrators, and policymakers. While some have argued for interventions in the early and middle grades (Hewson, Kahle, Scantlebury & Davies, 2001), public research universities represent a significant conduit in the STEM pipeline and are worth further examination.

As shown by Camp (1997), Sax (2000), and Seymour (2002), women’s underrepresentation in these fields at the undergraduate level also has long-term, negative reverberations in terms of potential graduate program enrollments and professional and academic careers in STEM fields. The same holds true for minority students. Underrepresentation of these groups is not only an ethical concern but is also of particular concern to policy-makers and business leaders (U.S. Department of Education, 2006). Thus, to better understand the preparation of a skilled, scientific workforce, it is important to consider the patterns of those who move through the STEM education pipeline, as well as the impact and responsibility of large, research-intensive, public universities in educating undergraduates in these fields.

Literature Review

Research on persistence of undergraduate students has determined that a number of factors explain minority and female students’ success in the sciences. May and Chubin (2003) categorized these factors as “pre-college preparation, recruitment programs, admissions policies, financial assistance, academic intervention programs, and graduate school preparation and admission" (p. 27). A number of these factors, including support systems at the college-level, have been found to be important for the general retention and persistence of minority students, not just those in STEM fields (Carter, 2006). Continuing research on persistence of underrepresented students is necessary, particularly in the STEM fields, because through the process of "uncovering differences in persistence patterns across diverse groups, we can illuminate factors that inhibit equal opportunity as well as policy factors that might be able to improve opportunity" (Carter, 2006, p. 34). Persistence also remains perhaps one of the most important topics to be studied within the issue of underrepresentation in STEM fields: "You can't play if you don't stay, and leaving science or premed for education or history usually means leaving science or premed forever" (Elliott et al., 1996, p. 700).

Below is a brief discussion of the factors that help to explain and predict persistence in STEM fields, as well as college majors in general. This discussion is not intended to be exhaustive, and other factors found in the literature can also be of equal importance in understanding persistence, including students' interest in and attitudes towards science (Hanson, 2004; Leppel, 2001; Levine & Wycokoff, 1991), perceived barriers to persistence (Brainard & Carlin, 1998), institutional effects (Elliott et al., 1996; Smyth & McArdle, 2004; Sonnert, Fox and Adkins, 2007), departmental effects (Etkowitz et al., 1994; Serex & Townsend, 1999), and intervention programs (Brainard & Carlin, 1998; Carter, 2006; Clewell & Campbell, 2002; Elliott et al., 1996).

Background Characteristics and Factors

Several studies have examined participation in STEM fields by individual background characteristics and factors. For instance, examining a cohort of students at 23 selective colleges and universities found that "Asians, also after accounting for effects of different gender distributions, were 2.6 times more likely than underrepresented minorities and 1.4 times more likely than Whites to persist in SME [Science, Math, and Engineering]" (Smyth & McArdle, 2004, p. 371). However, research using data from 175 institutions found that "race and gender had no bearing on persistence" (Tan, 2002, p. 9). Having family members and teachers that support a student's interests in and pursuit of science in high school may give students the confidence and support to persist in these fields during college, which was found to be true for African American students who persisted in biology at a predominately white institution (Russell & Atwater, 2005). Gender differences have been found to exist in the motivations to persist in STEM fields as "the kinds of contributions and discoveries that scientists and engineers make" (Grandy, 1998, p. 602) tend to be more important for men than women.

Academic Preparation and Performance

Similar to research on factors that lead to declaring a STEM major in college, academic preparation and performance in college are equally important to consider in regards to persistence in STEM fields. Academic preparation, as measured by standardized test scores and performance in high school math and science courses, are predictors of performance in college-level math and science courses, and for persistence in STEM fields (Elliott et al., 1996). In studying persistence in STEM fields at four Ivy League universities, Elliott et al. (1996) determined that academic preparation and performance as "preadmissions variables accounted for a significant fraction of the variance of persistence decisions and ethnicity did not" (Elliott et al., 1996, p. 695). This finding is important to discredit notions that certain populations of students are unable to remain in STEM fields based on their attributes, and provides evidence that factors other than one's race or gender are the reasons for differential persistence in the STEM fields. In addition, standardized test scores are significant predictors of all students persisting to their sophomore year in STEM majors (Tan, 2002)[1].

A study conducted at North Carolina State University on chemical engineering majors, compared the academic performance, course-taking patterns, and persistence in major of men and women from a single cohort of students (87 men and 34 women) (Felder et al., 1995). Academic performance relates to the differential decisions men and women make pertaining to their major. Upon failing a course in their major, men were found to be more likely to remain in chemical engineering and retake the course, while women were more likely to transfer to a new major. At the same time, women who perform well in their program and were on-schedule to finish their degree were still more likely than men to transfer to another major, indicating that decisions based on poor academic performance are not the only reasons women did not persist in the program. For students who failed a course, differences in the reasons for failing between men and women also explained their decision to remain in or transfer out of chemical engineering. Specifically, "women were more likely than the men to attribute poor performance to their own lack of ability and the men were more likely to attribute it to a lack of hard work or being treated unfairly" (Felder et al., 1995, p. 162). For those who persisted in the major, women reported high expectations of their academic ability at the start of their degrees, as well as more anxiety about their academic performance, yet this lowered as they continued their studies and was lower than the expectations of their male counterparts.

Financial Aid

Few studies have examined the impact of financial aid on students' persistence in STEM fields (St. John et al., 2004). Financial aid is an important factor to consider given that the amount,

[1] High standardized test scores can also result in students attending highly selective institutions, which are also shown to positively impact persistence in the STEM fields, regardless of students' race and/or gender (Tan, 2002).

quality, and mix of aid could impact the amount of time students can devote to their studies, an important factor in majors which require lab components for a number of courses. Overall, African American freshman who receive financial aid are more likely to persist in college overall than those who did not receive any financial aid (St. John et al., 2004). African American students enrolled in high-demand majors, such as Health, Business, and Engineering/Computer Science, are more likely to persist due to the perceived economic benefit of obtaining a job in that field following graduation (St. John et al., 2004), signaling "a nexus between students' financial reasons for attending college and their subsequent persistence behavior" (Carter, 2006, p. 41).

College Major and Persistence

Surprisingly, few empirical investigations have been conducted that specifically examine the differential role of college majors on minority students' persistence. St. John et al. (2004) attempted to address the lack of research in this specific area, using data from the Indiana Commission for Higher Education's Student Information System (ICHE-SIS) on White and African American freshman and sophomores enrolled in Indiana colleges and universities in 1996-1997. Their study determined that the choice of major field affected the persistence of students differently by race and ethnicity, with White freshman majoring in the social sciences less likely to persist, and African American sophomores majoring in health, business, and engineering/computer science more likely to persist. The potential return-on-investment to college major choice was found to impact decisions to persist in college, signifying that "the influence of majors that have higher potential economic returns (and more explicit linkages to employment) was greater for African Americans than for White students" (St. John et al., 2004, p. 226). While choosing to major in a STEM field, such as engineering and computer science, has long-term implications for those who wish to enter graduate programs or have careers in these areas, choosing these fields also seems to be "an important decision for African Americans because of its immediate impact on persistence" (St. John et al., 2004, p. 227).

A second study using ICHE-SIS data (St. John, Carter, Chung & Musoba, 2006) also found differences between racial groups in terms of how college major affected persistence. Declaring a major had a positive effect on White students' persistence, while no majors had a positive impact on African American's persistence and several, including computer science, even had negative impacts on their persistence. These two studies confirm the importance of investigating the relationship between differential rates of persistence for groups based on college majors, an area that should continue to be researched.

A separate study found that enrolling in a major associated with a specific profession, such as education, increased the likelihood of women's persistence, while business majors increased and education majors decreased men's persistence in college (Leppel, 2001). Examining the persistence of approximately 2,500 high-ability minority students, Grandy (1998) found that "commitment to S/E [science/engineering] during the sophomore year of college was the best determinant of persistence three years later" (p. 606), while a lack of commitment explained women switching to other majors. Convincing women to commit to the major may be a key to persistence and even to completing a STEM degree in 5 years (Clewell & Campbell, 2002).

Research Objectives

This study seeks to explore underrepresented students' persistence and degree attainment in STEM fields in comparison to that of their well-represented counterparts. Specific attention is given to comparing the persistence and degree attainment rates of women and minorities, as well as differences in these rates between different science-based fields. The following research questions are examined:

1. Based on initial major of choice, what are the persistence and graduation rates of underrepresented undergraduate students as compared to students form traditionally well-represented groups?
2. What is the conditional probability that a student will complete their degree in a specific length of time?
3. How might patterns of students' persistence and graduation rates differ within STEM fields?

Data

This study uses information on a single cohort of first-time freshmen who matriculated to three large, research-intensive universities in fall 1999. These universities are located in states that are in geographic proximity to one another. The academic careers of this cohort are tracked for a period of six years, allowing for persistence and educational outcomes across time to be examined. Of particular interest in this study are students' initial major, last major, and degree attainment status. Information on students' social backgrounds is also included in the dataset.

The data were originally compiled as part of a larger collection of several institutions' data coordinated by the Andrew W. Mellon Foundation, collectively referred to as the *Public University Database*. The cohort used in the analysis consists of over 16,377 first-time, full-time, domestic freshman who began college in fall 1999.

Methodology

The first research question is answered using a simplified version of event history analysis (Allison, 1994; DesJardins, 2003; Scott & Kennedy, 2005; Singer & Willett, 2003) for discrete time. The models preserve the time-to-event dimension of a typical event history analysis, but do not include additional time-invariant and -varying controls besides gender and race/ethnicity.[2] The estimates for each STEM field are generated separately, i.e., the models condition on one of the four initial major fields.

In order to compare various science-oriented fields, rather than simply focus on high-status STEM majors (e.g., engineering, computer science), a four-category taxonomy was used to differentiate between different categories of majors using the Classification of Instructional Programs (CIP) codes (see Appendix A). These categories are largely based on those used by the National Science Foundation (2008) in *Science and Engineering Indicators*, with some modifications. Majors were categorized as Science and Engineering, Agricultural and Biological Sciences, Health and Psychology, and Non-STEM fields and the models rerun to determine if who opts into each fields differs between these categories.

Estimation Strategy

The estimation procedure employed to address the first research question involves a simplified version of discrete-time event history analysis. The reduced-form model of degree attainment is expressed by the following equation

$$y^*_{it} = \alpha_t + \beta X_i \qquad (t = 1, \ldots, T)$$

$$y_{it} = 1 \text{ if } y^*_{it} > 0 \qquad \text{otherwise } y_{it} = 0$$

where y is the observed binary outcome, y^* is the unobservable propensity to complete a bachelor's degree, i denotes the student population of interest and t is the time period, which is an academic semester. Individual characteristics, X_i are fixed over time.

The statistical method used in this study to model the attainment of first-time students is an

[2] This decision was made because the data could not be properly prepared under the time constraints.

extension of the single-event, discrete-time hazard model (Allison, 1984; Singer & Willett, 2003). The discrete-time hazard function is the conditional probability that student i will earn a bachelor's degree in time period t given that either event had not occurred in an earlier time period. The basic discrete-time hazard function can be written as:

$$h_{it} = \Pr[y_t = t \mid y_t \geq t, X] \quad (1)$$

where h_{it} is the hazard function given that students have not dropped out or attained a degree before t; and observable heterogeneity is measured by the set of time-variant factors. Algebraically, assuming a logit link, the relationship in (1) can be written as:

$$\log_{it}(h_{it}) = \alpha + \beta X_i \quad (2)$$

In equation (2), by taking the log of the hazard, a linear relationship between the conditioning data and logit hazard has now been defined. The relationship between the predictors and the hazard are now nonlinear and analogous to the usual logistic regression model (Singer & Willett, 2003).

Discussion of Results

Analysis of the descriptive statistics will be discussed first, followed by the results of the conditional probabilities. The corresponding tables are available in Appendix B.

Social background

Table 1 offers an overview of the demographic and social background characteristics of the students in the dataset. Of the 16,377 students who entered in the three universities in fall 1999, 51 percent were male and 49 percent were female. In terms of the racial and ethnic composition of the students, 83 percent were White, 7 percent Asian, 5 percent Black, 4 percent were Hispanic, and approximately 2 percent were of another race.[3] Male and female representation within racial and

[3] Note that due to the small sample size, Native Americans (n=50) were merged into the "Other Race" category for the purpose of running the model, along with students with other or unknown race and ethnicity (n=267).

ethnic categories is approximately equal. The majority (78 percent) of students are in-state residents for each respective university. Of the students who reported their parent's highest level of education (approximately three-quarters), 63 percent of fathers had some college or higher and 60 percent of mothers had some college or higher.[4]

In terms of academic preparedness as measured by average total SAT score, men had a slightly higher average SAT score than did women (1189 and 1134, respectively). The average total SAT score was highest for students who entered Science and Engineering majors (1280), followed by Agricultural and Biological Sciences (1169), Health and Psychology (1126), and Non-STEM fields (1119). The average net price for the first year of attendance was $9,881. Interestingly, men paid a slightly higher net price ($10,149) as compared to the female members of the cohort ($9,611) in the first year of college.

Persistence in STEM Fields

The majority of students who start in a specific type of STEM major finish in the same type of major: 72 percent of students begin and end in a Science and Engineering major, 55 percent begin and end in a Agriculture and Biological Sciences major, 60 percent begin and end in a Health and Psychology major, and 86 percent of students begin and end in a non-STEM major (see Table 2).

However, important differences exist between subgroups. Table 3 shows that nearly 75 percent of men remain in Science and Engineering fields, compared to 66 percent of women. Slightly more women remain in the Agricultural and Biological Sciences as compared to men (59 percent versus 50 percent). Women also persist at a higher rate in Health and Psychology fields than do their male counterparts (65 percent versus 46 percent). Men and women persist in non-STEM fields at the same rate (88 percent each). Interestingly, women are twice as likely to switch from a

[4] Slightly more than one-quarter of mother and mother's highest level of education each is missing from the dataset.

Science and Engineering major to Agricultural & Biological Sciences (6 percent versus 3 percent), and are three times as likely as men to switch to a Health and Psychology major (6 percent versus 2 percent). These findings suggest that a higher percentage of women than men who depart Science and Engineering fields retain an interest in science.

Table 4 offers insight to the differences in persistence by race and ethnicity. Whites and Asians are most likely to remain in Science and Engineering fields (72 percent and 80 percent, respectively), while Blacks and Hispanics persist in these fields at lower rates (61 percent and 66 percent, respectively). Hispanic students are the most likely racial and ethnic group to remain in Agricultural and Biological Sciences (67 percent versus 56 percent of Whites, 40 percent of Blacks, and 55 percent of Asians). Likewise, Blacks are most likely to persist in Health & Psychology (65 percent versus 61 percent of Whites, 57 percent of Hispanics, and 51 percent of Asians). Whites and Hispanics are most likely to persist in non-STEM fields (89 percent each).

Similar to the finding that the women in the study retain an interest in science despite switching fields, Blacks and Hispanics who start in Science and Engineering are more likely than their White and Asian counterparts to enter Agricultural and Biological Sciences. In addition, Blacks are twice as likely as Whites and Asians to enter Health and Psychology upon leaving Science and Engineering (6 percent versus 3 percent). Over 20 percent of Blacks who begin their collegiate studies in Agricultural and Biological Sciences switch to a program of study in Health and Psychology, as compared to 14 percent of Hispanics, eight percent of Whites and five percent of Asians. Again, this demonstrates that although Blacks and Hispanics persist at a lower rate in Science and Engineering fields, not all who switch majors abandon science. Instead, a portion of these underrepresented students retain an interest in science by entering other science-based fields.

Graduation Rates by Persistence Status

Table 5 provides an overview of the six year graduation rates of students according to their major field persistence status. Surprisingly, students who switched from their freshman year major were more likely to graduate as compared to students who did not switch from their first declared major (80 percent versus 71 percent). This observation holds true across all subgroups of interest, although the graduation rate gaps between switchers and non-switchers varies greatly. The difference in graduation rates for Asian students who persisted in their original major versus those who switched is only 2 percent, as compared to 8 percent for Whites, 17 percent for Blacks, and 13 percent for Hispanics. Men who began in Health and Psychology and who did not switch majors were least likely to graduate compared to men in other fields (43 percent). Women who persisted in Science and Engineering have higher graduation rates than males who persisted in these fields (81 percent versus 78 percent). Hispanics who persist in Agricultural and Biological Sciences, and Blacks who persist in Health and Psychology have comparable graduation rates as their White colleagues in the same fields.

Conditional Probabilities Results

As described above, the conditional probabilities analysis used in this study reflect the enrollments of students and degrees attained. As a reminder, a discrete-time hazard is the conditional probability that individual *i* will experience a particular event or outcome in time period *t*, given that he or she did not experience the same outcome in an earlier time period. Overall, 42 percent of students who began their studies in Fall 1999 earned their bachelor's degree in Spring 2003 (see Table 6). Approximately an additional 25 percent earn their degree in the following year, or by Spring 2004. Nearly half of students enrolled in Agricultural and Biological Sciences and Non-STEM fields graduated in Spring 2003, or four years after matriculation, while 37 percent of students in Science and Engineering and Health and Psychology graduate in the same time period. An additional 33 percent of Science and Engineering majors graduate by the end of their fifth year, as compared to 21 percent of Agricultural and Biological Science majors, 19 percent of Health and

Psychology majors, and 21 percent of Non-STEM majors.

Table 7 shows that within Science and Engineering majors, a larger percentage of White, Black, and Asian females complete their degrees in four years than do their male counterparts (45 percent of White females versus 35 percent of White males; 21 percent of Black females versus 15 percent of Black males, 58 percent of Asian females versus 45 percent of Asian males). Approximately the same percentage of Hispanic males and females in Science and Engineering majors complete their degrees in four years (21 percent of females versus 22 percent of males). In addition, 77 percent of White females finish within five years of matriculation, as compared to 70 percent of White males. A greater five-year graduation gap exists for Hispanic students in Science and Engineering majors, with 71 percent of Hispanic females completing their degrees in five years as compared to only 51 percent of Hispanic males. Although there are fewer females pursuing these majors, a higher percentage of them complete their bachelor's degrees in a shorter time period than their male counterparts.

A similar pattern of conditional probabilities exist in the Agricultural and Biological Sciences. Within each racial and ethnic category, females are more likely to graduate in four years as compared to their male counterparts (54 percent of White females versus 39 percent of White males; 32 percent of Black females versus 21 percent of Black males; 38 percent of Hispanic females versus 22 percent of Hispanic males; 68 percent of Asian females versus 34 percent of Asian males). A higher percentage of females in each racial and ethnic group are likely to graduate in five years as compared to their male counterparts enrolled in these fields. Similar findings exist when examining the conditional probabilities of obtaining a bachelor's degree in Health and Psychology. Females across all racial and ethnic groups are also more likely to complete a degree in non-STEM fields in four and five year periods, although the difference between probabilities by gender is smaller within these majors.

Policy and Program Implications

A better understanding of the key factors that affect underrepresented students' perseverance and degree completion in the STEM fields will help policymakers and postsecondary administrators design programs to promote persistence and completion so that students can benefit more fully from their education in terms of potentially entering graduate programs in related fields, earning higher incomes, experiencing greater social mobility, and benefiting from enhanced professional opportunities. In addition, the use of a comprehensive, longitudinal dataset that combines data from multiple institutions allows for information to be obtained on persistence and degree attainment patterns of underrepresented students at large, research-intensive public universities.

The findings of this study, while exploratory, points to important differences between traditionally underrepresented and well-represented groups in the STEM fields. Women and minorities do retain an interest in science even though many depart high-profile majors, such as computer science and engineering. This is evidenced by their switching into other science-based fields, such as the agricultural and health sciences. This finding, along with an expanded notion of what constitutes STEM fields, challenges the notion that a departure from the high-profile STEM fields is a loss to the science community, or that women and minorities are simply not interested in science. By following which fields students enter into upon switching majors, what may be initially perceived to be a negative outcome may actually be participation—and eventually success—in another science-based field.

In addition, women's shorter time-to-degree across a wide variety of science-based fields as compared to men has important implications for when members of these groups are eligible to enter graduate programs and STEM careers. This finding is encouraging, and is likely impacted by the many intervention programs that are offered on college campuses, such as the three large, research-intensive, public universities in this study. Brainard & Carlin (1998) note the importance of support systems in helping students negotiate, manage, and overcome the perceived barriers to their success. While not observable in the database, some of the success of women and minority women is likely to be attributed to such programs.

Despite these positive findings, there is still evidence that issues of access to the STEM fields exist for women and minorities. While students self-select into their major field of choice, institutions may use mechanisms like grants to increase the likelihood of underrepresented students initially choosing a STEM major (Kienzl, George-Jackson, and Trent, 2009).

Limitations and Future Research

A number of limitations exist in this study. First, the data are drawn from a single cohort of students attending three institutions, which limits the generalizability of these findings. Selection bias is present in the dataset due to the data comprising only of students who attended these three universities and does not include data on students who applied or who were admitted but did not enroll. In addition, students may be self-selecting into specific majors based on interests, motivations, and orientations to future careers; all of which are unobservable in the dataset.

Some of these limitations will be addressed as this research moves forward. Recognizing that some factors, such as overall academic performance or academic performance in a specific course may prompt students to switch majors, transcript data will be examined in a future study to identify potential “gatekeeping” courses. In addition, regression analysis will offer insight into how other factors, such as parent’s level of education, amount or type of financial aid, and residency status, might explain students’ persistence in a major, as well as time-to-degree. Of equal importance will be to investigate at what point in the degree program movements between majors occur, with consideration given to overall academic performance and financial aid status, as these factors may contribute to a change in major field of choice. Given what is known from the literature review, it is expected that financial aid information will help explain persistence and degree attainment patterns. Of the 16,377 students in the database, over 10,000 filed for FAFSA, offering a wealth of information regarding the type, amount, and mix of financial aid received throughout the course of their undergraduate studies. The authors hope to further the discussion of the impact of financial aid on college persistence, major field persistence, and degree attainment.

In continuing these lines of research, the authors hope to continue to contribute to the understanding of underrepresented students' persistence and educational outcomes as they pertain to the STEM fields, but also to investigate the impact of large, research-intensive, public universities on the production of female and minority STEM graduates, particularly as these institutions "are the primary producers of the nation's scientific brain trust" (Fields, 1998, p. 16). This study, and future studies, has implications not only for institutional programs and policies that meet social and practical concerns, but also state and federal policies regarding the preparation of a skilled, scientific workforce.

References

Allison, P. (1984). *Event history analysis: Regression for longitudinal data* (Sage University paper series on quantitative applications in the social sciences, Number 07-046). Beverly Hills, CA: Sage.

Brainard, S.G., & Carlin, L. (1998). *A longitudinal study of undergraduate women in engineering and science*. Proceedings of the 1997 Frontiers in Education Conference, November 5-8, 1997, Pittsburgh, PA. Retrieved June 10, 2008, from http://www.iwitts.com/html/brainard.pdf

Camp, T. (1997). The incredible shrinking pipeline. *Communications of the ACM*, *40*(10), 103-110.

Carter, D.F. (2006). Key issues in the persistence of underrepresented minority students. *New Directions for Institutional Research. 130*, 33-46.

Clewell, B.C., & Campbell, P.B. (2002). Taking stock: Where we've been, where we are, where we're going. *Journal of Women and Minorities in Science and Engineering, 8*, 255-284.

DesJardins, S.L. (2003). Event history methods: Conceptual issues and an application to student departure from college. In J. C. Smart (Ed.), *Higher education: Handbook of theory and research*, Vol. 18 (pp.421–471). Dordrecht, Netherlands: Springer.

Elliot, R, Strenta, A.C., Adair, R., Matier, M., & Scott, J. (1996). The role of ethnicity in choosing and leaving science in highly selective institutions. *Research in Higher Education, 37*(6), 681-709.

Etkowitz, H., Kemelogor, C., Neuschatz, M., Uzzi, B., & Alonzo, J. (1994). The paradox of critical mass for women in science (change in workplace structure needed to integrate women successfully into academic science departments). *Science, 266*(5182), 51-54.

Felder, R.M., Felder, G.N., Mauney, M., Hamrin, C.E., & Dietz, E.J. (1995). A longitudinal study of engineering student performance and retention: Gender differences in student performance and attitudes. *Journal of Engineering Education, 84*(2), 151-163.

Grandy, J. (1998). Persistence in science of high ability minority students. *The Journal of Higher Education, 69*(6), 589-620.

Hanson, S.L. (2004). African American women in science: Experiences from high school through the post-secondary years and beyond. *National Women's Study Association Journal, 16*(1), 96-115.

Hewson, P.W., Kahle, J.B., Scantlebury, K. & Davies, D. (2001). Equitable science education in urban middle schools: Do reform efforts make a difference? *Journal of Research in Science Teaching*, *38*(10), 1130–1144.

Kienzl, Gregory S., George-Jackson, Casey E., & Trent, William T. (2009). *Underrepresented*

Students Entering STEM Fields. American Educational Research Association. April 13-17, 2009. San Diego, CA.

Leppel, K. (2001). The impact of major on college persistence among freshmen. *Higher Education, 41*(3), 327-342.

Levine, J., & Wycokoff, J. (1991). Predicting Persistence and Success in Baccalaureate Engineering. *Education, 111*(4), 461-468.

May, G.S & Chubin, D.E. (2003) A retrospective on undergraduate engineering success for underrepresented minority students. *Journal of Engineering Education, 92*(1), 27-40.

Oakes, J. (1990). Opportunities, achievement, and choice: Women and minority students in science and mathematics. *Review of Research in Education*, *16*, 153–222.

National Science Foundation (2008) *Science and Engineering Indicators*. Retrieved February 19, 2009, from http://www.nsf.gov/statistics/seind08/c2/c2s3.htm#c2s31

Russell, M.L., & Atwater, M.M. (2005). Traveling the road to success: A discourse on persistence throughout the science pipeline with African American students at Predominately White Institutions. *Journal of Research in Science Teaching, 42*(6), 691-715.

Sax, L.J. (2000). Undergraduate science majors: Gender differences in who goes to graduate school. *The Review of Higher Education*, 24(2), 153–172.

Scott, M. & Kennedy, B. (2005). Pitfalls in pathways: Some perspectives on competing risks event history analysis in education research. *Journal of Educational and Behavioral Statistics*, 30(4), 413–442.

Serex, C.P., & Townsend, B.K. (1999). Student perceptions of chilling practices in sex-atypical majors. *Research in Higher Education, 40*(5), 527-538.

Seymour, E. (2002). Tracking the processes of change in U.S. undergraduate education in science, mathematics, engineering, and technology. *Science Education*, *86*, 79–105.

Singer, J. & Willett, J. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence*. New York: Oxford University Press.

Smyth, F. L., & McArdle, J. J. (2004). Ethnic and Gender Differences in Science Graduation at Selective Colleges with Implications for Admission Policy and College Choice. *Research in Higher Education, 45*(4), 353-381.

Sonnert, G., Fox, M. F., & Adkins, K. (2007). Undergraduate Women in Science and Engineering: Effects of Faculty, Fields, and Institutions Over Time. *Social Science Quarterly, 88*(5), 1333-1356.

St. John, E.P., Carter, D.F., Chung, C.G., and Musoba, G.D. (2006). “Diversity and persistence in Indiana Higher Education: The impact of preparation, major choices, and student aid." In E.P. St. John (Ed.). *Readings on Equal Education, Vol. 21: Public Policy and Educational Opportunity: School Reforms, Postsecondary Encouragement, and State Policies on Higher Education*. New York: AMS Press.

St. John, E. P., Hu, S., Simmons, A., Carter, D. F., & Weber, J. (2004). What Difference Does a Major Make? The Influence of College Major Field on Persistence by African American and White Students. *Research in Higher Education, 45*(3), 209-232.

Stake, J.E. & Mares, K.R. (2001). Science enrichment programs for gifted high school girls and boys: Predictors of program impact on science confidence and motivation. *Journal of Research in Science Teaching*, *38*(10), 1065–1088.

Tan, D.L. (2002). *Majors in science, technology, engineering, and mathematics: Gender and ethnic differences in persistence and graduation*. 42nd Annual Association for Institutional Research (AIR) Forum. June 3-6, 2002, Toronto, Canada.

U.S. Department of Education. (2006). *A test of leadership: Charting the future of U.S. higher education*. Washington, DC: Author. Retrieved September 28, 2006, from http://www.ed.gov/about/bdscomm/list/hiedfuture/reports/pre-pub-report.pdf.

Appendix A

Science and engineering	
Mathematics	
27.01	Mathematics, general
27.03	Applied mathematics
27.05	Mathematical statistics
27.99	Mathematics/statistics, other
52.1302	Business statistics
52.1304	Actuarial science
Aeronautical/astronautical engineering	
14.02	Aerospace, aeronautical, astronautical engineering
Chemical engineering	
14.07	Chemical engineering
14.25	Petroleum engineering
14.32	Polymer/plastics engineering
Civil engineering	
14.04	Architectural engineering
14.08	Civil engineering
14.14	Environmental/environmental health engineering
14.09	Computer engineering
14.10	Electrical, electronics, communications engineering
14.38	Surveying engineering
Mechanical engineering	
14.11	Engineering mechanics
14.19	Mechanical engineering
Materials/metallurgical engineering	
14.06	Ceramic sciences/engineering
14.18	Materials engineering
14.20	Metallurgical engineering
14.31	Materials science
Other engineering	
14.01	Engineering, general
14.03	Agricultural engineering
14.05	Bioengineering/biomedical engineering
14.12	Engineering physics
14.13	Engineering science
14.15	Geological engineering
14.16	Geophysical engineering
14.21	Mining/mineral engineering
14.22	Naval architecture/marine engineering
14.23	Nuclear engineering
14.24	Ocean engineering
14.27	Systems engineering
14.28	Textile sciences/engineering
14.29	Engineering design
14.34	Forest engineering
14.37	Operations research
14.39	Geological engineering

14.99	Engineering, other
Computer sciences	
11.01	Computer/information sciences, general
11.02	Computer programming
11.03	Data processing technology/technician
11.04	Information sciences/systems
11.05	Computer systems analysis
11.07	Computer science
11.08	Web page design, computer graphics, database management
11.09	Computer systems networking and telecommunications
11.10	System administration, networking, management
11.99	Computer/information sciences, other
Astronomy	
40.0201	Astronomy
40.0202	Astrophysics
40.0299	Astronomy/astrophysics, other
Chemistry	
40.0501	Chemistry, general
40.0502	Analytical chemistry
40.0503	Inorganic chemistry
40.0504	Organic chemistry
40.0506	Physical/theoretical chemistry
40.0507	Polymer chemistry
40.0508	Chemical physics
40.0599	Chemistry, other
51.2004	Medicinal/pharmaceutical chemistry
Physics	
40.0801	Physics, general
40.0802	Chemical and atomic/molecular physics
40.0804	Elementary particle physics
40.0805	Plasma/high-temperature physics
40.0806	Nuclear physics
40.0807	Optics/optical sciences
40.0808	Solid state/low-temperature physics
40.0809	Acoustics
40.0810	Theoretical/mathematical physics
40.0899	Physics, other
Other physical sciences	
40.01	Physical sciences, general
40.99	Physical sciences, other
Atmospheric sciences	
40.0401	Atmospheric sciences/meteorology, general
40.0402	Atmospheric chemistry/climatology
40.0403	Atmospheric physics/dynamics
40.0404	Meteorology
40.0499	Atmospheric science/meteorology, other
Earth sciences	
40.0601	Geology
40.0602	Geochemistry

40.0603	Geophysics/seismology
40.0604	Paleontology
40.0605	Hydrology/water resources sciences
40.0606	Geochemistry/petrology
40.0699	Geological and related sciences, other
Oceanography	
40.0607	Oceanography

Agricultural and Biological Sciences	
Agricultural sciences	
01.04	Agricultural and food products processing
01.05	Agricultural and domestic animal services
01.08	Agriculture extension/communications
01.09	Animal sciences
01.10	Food sciences/technology
01.11	Plant sciences
01.12	Soil sciences
01.99	Agriculture/agricultural sciences, other
03.01	Natural resources conservation
03.02	Natural resources management/protective services
03.03	Fishing and fisheries sciences/management
03.05	Forestry/forest management
03.06	Wildlife/wildlands management
03.99	Natural resources conservation, other
26.0707	Agricultural animal physiology
Biological Sciences	
19.0505	Food systems administration
26.01	Biology, general
26.0202	Biochemistry
26.0203	Biophysics
26.0204	Molecular biology
26.0209	Radiation biology/radiobiology
26.03	Botany/plant biology
26.0401	Cell/cellular biology and histology
26.0403	Anatomy
26.0405	Neurosciences
26.05	Microbiology/bacteriology
26.0503	Medical microbiology/bacteriology
26.0504	Virology
26.0505	Parasitology
26.0599	Immunology
26.07	Zoology
26.08	Genetics, plant/animal
26.09	Medical neurobiology
26.0910	Pathology

26.10	Pharmacology/toxicology
26.1101	Biometrics
26.1102	Biostatistics
26.12	Biotechnology research
26.13	Ecology
26.1302	Marine/aquatic biology
26.1303	Evolutionary biology
26.99	Biological sciences/life sciences, other
30.10	Biopsychology
30.19	Nutritional sciences
30.24	Neuroscience

Health and Psychology

Medical sciences	
51	Health professions/related clinical sciences
60.01	Dentistry
60.02	Medicine/surgery
Medical sciences, continued	
60.03	Veterinary medicine
26.0988	Medical physiology
Psychology	
42.01	Psychology, general
42.02	Clinical psychology
42.03	Cognitive psychology/psycholinguistics
42.04	Community psychology
42.05	Comparative psychology
42.06	Counseling psychology
42.07	Developmental/child psychology
42.08	Experimental psychology
42.09	Industrial/organizational psychology
42.10	Personality psychology
42.11	Physiological psychology/psychobiology
42.16	Social psychology
42.19	Psychometrics
42.20	Clinical child psychology
42.21	Environmental psychology
42.22	Geropsychology
42.23	Health/medical psychology
42.24	Psychopharmacology
42.25	Family psychology
42.26	Forensic psychology
42.99	Psychology, other
51.1507	Psychoanalysis
51.3603	Hypnotherapy

Non-STEM

Education	
13	Education
31.05	Health/physical education
39.0401	Religious education
42.1701	School psychology
42.1801	Educational psychology
51.0913	Athletic training/trainer
English/literature	
16.0104	Comparative literature
23	American/English languages, literatures
Foreign languages/literatures	
16	Foreign languages/literatures
16.1200	Classics/languages
History	
54	History
Religion/theology	
38.02	Religious studies
39	Theology/ministries
Other humanities	
24	Liberal arts/other humanities
38.01	Philosophy
50	Visual/performing arts
Business/management	
01.01	Agricultural business/management
01.03	Agricultural production operations
Business/management, continued	
01.06	Horticultural operations
14.3701	Operations research
52	Business, management, marketing, related support services
Information fields (journalism, broadcasting, librarianship)	
09	Communications
10	Communications technologies
25	Library science
Other professional fields	
04	Architecture/related programs
12	Personal/culinary services
15	Engineering-related technologies
19	Home economics/family studies
22	Law and legal studies
28	Reserve officer training corps (ROTC)
29	Military technologies
30	Multi-/interdisciplinary studies
31	Parks/recreation/leisure/fitness
32	Basic skills
33	Citizenship activities
34	Health related knowledge/skills
35	Interpersonal/social skills

36	Personal awareness/self-improvement
41	Science technologies
43	Protective services
44	Public administration/social services professions
46	Construction trades
47	Mechanic/repair technologies
48	Precision production trades
49	Transportation/materials moving workers
Political science	
44.04	Public administration
44.05	Public policy analysis
44.99	Public administration/services, other
45.09	International relations/affairs
45.10	Political science/government
Sociology	
45.05	Demography/population studies
45.0702	Cartography
45.11	Sociology
Other social sciences	
05	Area, ethnic, cultural, gender studies
16.0102	Linguistics
30.1101	Gerontology
30.1501	Science, technology, society
30.1701	Behavioral sciences
30.2001	International/global studies
30.2301	Intercultural/multicultural and diversity studies
45.01	Social sciences, general
45.02	Anthropology
45.03	Archeology
45.04	Criminology
45.07	Geography
45.10	Canadian government/politics
45.12	Urban affairs/studies
45.99	Social sciences/history, other
53.3201	Bioethics/medical ethics
54.0000	Social sciences/history
54.0404	History/philosophy of science and technology
Economics	
01.0103	Agricultural economics
45.06	Economics

Appendix B

Table 1. Descriptive statistics of first-time freshmen in 1999 by selected demographic characteristics, 1999

	Overall	Male	Female	Science & Engineering	Agriculture	Health	Non-STEM
Socio-demographic							
Female	48.7			22.0	54.4	75.7	53.7
White, non-Hispanic	82.8	82.8	82.9	81.5	83.2	85.0	82.9
Black, non-Hispanic	4.6	3.8	5.5	2.8	3.9	5.1	5.4
Hispanic	3.6	3.6	3.5	2.9	2.9	3.4	4.0
Asian	7.0	7.6	6.3	10.5	8.1	5.2	5.7
Other	2.0	2.1	1.8	2.3	1.9	1.4	1.9
Father ed: >HS diploma	62.9	64.9	60.9	69.9	63.5	59.4	60.4
Mother ed: >HS diploma	60.0	61.2	58.7	66.3	61.9	56.7	57.6
Resident of state	78.3	76.2	80.6	71.2	86.5	82.2	79.3
SAT score	1163	1189	1134	1280	1169	1126	1119
Financial aid							
Completed FAFSA	72.9	71.2	74.7	74.5	72.7	79.7	70.9
Received a Pell grant	14.9	13.4	16.3	12.3	14.8	16.7	15.6
Net price	$9,881	$10,149	$9,611	$10,561	$9,597	$9,406	$9,732
Observations	16,377	8,331	7,892	3,884	1,455	1,841	9,197

Source: Public University Database (2009). Author's calculations.

Table 2. Degree of switching majors of first-time freshmen, 1999-2005

	Last declared major				
First declared major	Science & Engineering	Agricultural & Biological Sciences	Health & Psychology	Non-STEM	Total
Science & Engineering	72.3	3.7	2.8	21.3	100.0
	2,806	142	107	829	3,884
Agricultural & Biological Sciences	5.8	55.3	8.7	30.2	100.0
	85	805	126	439	1,455
Health & Psychology	2.0	6.3	60.1	31.7	100.0
	36	115	1,107	583	1,841
Non-STEM	3.1	2.8	5.6	88.5	100.0
	285	256	519	8,137	9,197
Total	19.6	8.1	11.4	61.0	100.0
	3,212	1,318	1,859	9,988	16,377

Source: Public University Database (2009). Author's calculations.

Table 3. Degree of switching majors of first-time freshmen by gender, 1999-2005

	Last declared major							
	Science & Engineering		Agricultural & Biological Sciences		Health & Psychology		Non-STEM	
First declared major	Male	Female	Male	Female	Male	Female	Male	Female
Science &	74.1	65.7	3.0	5.9	1.8	6.3	21.1	22.2
Engineering	2,246	560	92	50	53	54	640	189
Agricultural &	9.9	2.4	50.6	59.3	4.1	12.5	35.4	25.8
Biological Sciences	66	19	336	469	27	99	235	204
Health &	4.3	1.2	11.0	4.7	46.1	64.6	38.7	29.4
Psychology	19	17	49	66	206	901	173	410
Non-STEM	4.8	1.6	3.0	2.6	3.5	7.5	88.7	88.3
	204	81	126	130	150	369	3,779	4,358
Total	30.2	8.5	7.2	9.0	5.2	17.8	57.5	64.7
	2,535	677	603	715	436	1,423	4,827	5,161

Source: Public University Database (2009). Author's calculations.

Table 4. Degree of switching majors of first-time freshmen by race/ethnicity, 1999-2005

First declared major	Last declared major															
	Science & Engineering				Agricultural & Biological Sci				Health & Psychology				Non-STEM			
	White	Black	Hispanic	Asian	White	Black	Hispanic	Asian	White	Black	Hispanic	Asian	White	Black	Hispanic	Asian
Science and	72.0	61.1	65.8	79.6	3.4	5.6	5.4	4.7	2.7	5.6	1.8	3.0	21.9	27.8	27.0	12.8
Engineering	2,271	66	73	324	108	6	6	19	85	6	2	12	692	30	30	52
Agricultural &	5.2	3.5	9.5	12.0	55.8	40.4	66.7	54.7	8.2	22.8	14.3	5.1	30.8	33.3	9.5	28.2
Biological Sci	63	2	4	14	673	23	28	64	99	13	6	6	371	19	4	33
Health &	1.6	1.1	1.6	9.5	6.1	5.4	3.3	10.5	60.6	65.2	57.4	50.5	31.8	28.3	37.7	29.5
Psychology	24	1	1	9	94	5	2	10	935	60	35	48	491	26	23	28
Non-STEM	2.7	3.4	3.0	9.1	2.9	1.8	1.9	3.3	5.5	9.9	6.5	3.9	89.0	84.8	88.6	83.7
	201	17	11	47	216	9	7	17	413	49	24	20	6,704	419	325	431
Total	19.0	11.5	15.3	34.7	8.1	5.7	7.4	9.7	11.4	17.0	11.5	7.6	61.4	65.8	65.8	48.0
	2,559	86	89	394	1,091	43	43	110	1,532	128	67	86	8,258	494	382	544

Source: Public University Database (2009). Author's calculations.

Table 5. Graduation rates of first-time freshmen who switched majors by initial major, gender, and race/ethnicity, 1999-2005

	Switched majors							
	Male	Female	White	Black	Hispanic	Asian	Other	Total
Science & Engineering	74.1	84.3	78.0	64.3	71.1	77.1	65.4	76.9
Agricultural & Biological	79.6	82.9	81.6	73.5	78.6	83.0	78.6	81.2
Health & Psychology	74.3	81.3	80.1	65.6	73.1	74.5	80.0	79.0
Non-STEM	83.8	83.8	84.7	82.7	76.2	85.7	60.0	83.8
Total	77.6	83.0	81.1	73.8	74.2	80.5	68.6	80.2

	Did not switch							
	Male	Female	White	Black	Hispanic	Asian	Other	Total
Science & Engineering	77.7	80.7	79.1	53.0	57.5	85.8	63.5	78.3
Agricultural & Biological	58.0	75.9	69.5	43.5	64.3	70.3	61.5	68.4
Health & Psychology	43.2	60.9	58.3	56.7	45.7	62.5	33.3	57.6
Non-STEM	67.6	73.9	72.2	58.2	64.0	76.3	55.1	71.0
Total	69.8	72.8	72.3	56.9	61.6	78.7	56.3	71.3

Source: Public University Database (2009). Author's calculations.

Table 6. Conditional enrollment and completion probabilities by initial major, 1999-2005

	Science & Engineering		Agricultural & Biological Sciences		Health & Psychology		Non-STEM		Total	
	Enrolled	Attained degree	Enrolled	Attained degree	Enrolled	Attained degree	Enrolled	Attained degree	Enrolled	Attained degree
Fall 1999	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
Spring 2000	96.1	0.0	95.3	0.0	94.5	0.0	95.1	0.0	95.3	0.0
Fall 2000	89.5	0.0	88.9	0.0	85.4	0.0	86.8	0.0	87.5	0.0
Spring 2001	85.8	0.0	84.1	0.0	81.9	0.0	83.0	0.0	83.7	0.0
Fall 2001	83.3	0.1	80.1	0.0	77.0	0.1	78.7	0.0	79.7	0.0
Spring 2002	82.2	0.6	79.0	0.8	76.7	0.4	77.5	0.6	78.7	0.6
Fall 2002	79.8	1.7	76.6	2.1	73.5	2.4	75.6	1.8	76.5	1.9
Spring 2003	77.7	36.7	74.2	45.9	70.5	37.4	73.0	44.4	74.0	41.9
Fall 2003	41.7	15.0	27.4	9.6	32.5	9.4	27.5	11.0	31.4	11.6
Spring 2004	27.2	18.3	18.1	11.8	23.5	9.8	16.1	10.4	19.8	12.3
Fall 2004	8.9	2.5	6.5	1.9	13.6	1.2	5.1	1.8	7.1	1.9
Spring 2005	6.3	1.7	4.9	1.6	12.4	3.3	3.4	1.3	5.2	1.6

Source: Public University Database (2009). Author's calculations.

Table 7. Conditional attainment probabilities for four, five and six year graduation rates by initial major, gender and race/ethnicity, 1999-2005

		White		Black		Hispanic		Asian	
		Male	Female	Male	Female	Male	Female	Male	Female
Science & Engineering	Spring 2003	34.7	44.4	14.8	21.3	21.8	20.8	45.4	57.6
	Fall 2003	16.3	12.8	14.8	14.9	13.8	20.8	10.2	14.1
	Spring 2004	18.3	20.2	13.1	12.8	14.9	29.2	17.8	10.9
	Fall 2004	2.9	1.8	0.0	6.4	1.1	0.0	1.6	2.2
	Spring 2005	1.9	0.9	0.0	6.4	4.6	4.2	0.6	1.1
Agricultural & Biological Sciences	Spring 2003	38.9	53.6	21.1	31.6	22.2	37.5	34.4	67.9
	Fall 2003	9.9	9.1	10.5	15.8	5.6	16.7	9.8	3.6
	Spring 2004	14.4	8.6	10.5	21.1	27.8	16.7	14.8	7.1
	Fall 2004	2.4	1.4	0.0	0.0	0.0	0.0	4.9	1.8
	Spring 2005	2.6	0.9	0.0	0.0	5.6	0.0	3.3	1.8
Health & Psychology	Spring 2003	30.8	40.9	10.0	34.7	20.0	37.3	48.1	32.4
	Fall 2003	9.3	10.0	0.0	4.2	10.0	5.9	3.7	8.8
	Spring 2004	12.5	7.9	30.0	16.7	0.0	5.9	3.7	17.6
	Fall 2004	1.6	1.3	0.0	2.8	0.0	0.0	0.0	0.0
	Spring 2005	3.7	3.3	0.0	4.2	0.0	2.0	3.7	2.9
Non-STEM	Spring 2003	38.9	52.2	22.4	36.4	28.3	43.9	39.5	52.8
	Fall 2003	12.8	9.3	11.4	10.5	16.0	8.9	12.9	10.3
	Spring 2004	11.7	8.9	14.2	10.2	15.5	8.9	10.3	9.6
	Fall 2004	2.0	1.4	4.6	3.6	2.1	1.7	3.4	1.8
	Spring 2005	1.7	0.7	2.3	3.6	0.5	1.7	2.1	0.7