DRAFT: DO NOT CITE WITHOUT **AUTHORS' PERMISSION**

Underrepresented Students Entering STEM Fields

Gregory S. Kienzl[1]
Casey E. George-Jackson
William T. Trent

Educational Policy Studies
University of Illinois at Urbana-Champaign

[1] Corresponding author: gkienzl@illinois.edu

We would like to thank the Sloan Foundation for their generous support of this project and the Mellon Foundation for allowing us access to their data. All errors or omissions are our responsibility.

Abstract

This study will examine the factors that explain the matriculation of first-time women and minority undergraduate students in STEM (science, technology, engineering, and mathematics) fields at three large, research-intensive, public universities. Specifically, the following questions will be addressed: What *factors influence students' entrance into the STEM fields?* and *How might patterns of students opting in differ within STEM fields?* These questions are explored using descriptive statistics and nested logistic regression models with socio-demographic characteristics, pre-college academic qualifications and financial attributes included as explanatory variables. The results of this study will help contribute to institutional effectiveness by identifying potential mismatches in the initial choice of college major and offering policy improvements that satisfy both educational and diversity goals.

Introduction

The STEM (science, technology, engineering and mathematics) education pipeline—from primary education through secondary and postsecondary levels—has been widely studied in an concerted effort to pinpoint periods or circumstances that both preclude and permit students to becoming involved in STEM fields (and eventually STEM occupations). Despite the increased attention, the number of women and non-Asian minorities (hereafter, "underrepresented") students in the STEM pipeline has only modestly improved over the past three decades. A considerable disparity still exists between well-represented (i.e., men, whites, Asians, and non-Pell eligible students) and underrepresented populations in these fields (Oakes, 1990; Stake & Mares, 2001).

Moreover, as Seymour (2002) notes, the undergraduate STEM pipeline becomes narrower for women and minority students as compared to white males who persist at higher rates in the same fields. Departures from the STEM fields can be explained by a combination of individual, institutional and societal factors, including differential academic preparation, negative experiences with science, pedagogy which benefits traditionally represented groups, chilling climates, and how individuals are socialized. Even more importantly, a narrowing pipeline for women and minorities has broad implications for graduate study and, ultimately, entry to the STEM labor market.

Grandy (1998) and Seymour (2002) argue that the need to diversify STEM fields is an issue of access and equity for populations who have historically marginalized. The breadth and depth of research reflects not only the need for qualified individuals to enter the growing scientific workforce, but also increases in the number of programs designed to expand access to the STEM fields. 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 graduate program enrollment and professional and academic careers in STEM fields, which further erodes and threatens state and national economic competitiveness. The same holds true for minority and low-income students, particularly as low-income students may be deterred from pursuing degrees in STEM fields due to higher costs (i.e., higher tuition and opportunity costs as compared to other majors) and longer time-to-degree, which may delay entry in the labor market.

In short, the diversification of higher education that has occurred due to major societal, programmatic, and policy changes and efforts in the last 40 years has not been fully realized in the nation's top colleges and universities, or in specific fields such as the STEM fields. Minorities and women remain underrepresented in the sciences, even though these populations have increased their representation and participation in other areas of higher education and in the workforce (Rosenbloom, et al., in press). The factors that contribute to the challenges of access for underrepresented students, 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), large, public research universities represent a significant conduit in the pipeline and deserve further inspection. Thus, this study will estimate the effect of individual and institutional factors on underrepresented students' enrollment in STEM fields in comparison to that of their well-represented counterparts. By specifically modeling initial major choice, this study provides a more accurate picture of the matriculation decisions of underrepresented students in STEM fields during a critical period in postsecondary education.

Literature Review

A number of important background factors affect student's entry into STEM fields. Factors such as high school characteristics, the number and level of science and math courses offered, the number of math and science Advanced Placement (AP) courses available, access to laboratories, types of college preparatory and career course offerings, and resources available to high schools and the communities they serve have all been examined and shown to play an important role.

Although mentioned here, we cannot test these factors with the data available for our study. On the other hand, we have information on student's socioeconomic status, parents' level of education, student's academic preparedness for college, and the cost of attendance for pursuing a given college major.[1] These factors, which have also been shown to influence students' choice of major, form the backbone of the current study and are worth further discussion. For example, research has investigated the connection between a student's choice of major and student's socioeconomic status, academic preparedness, locus of control, expected economic returns, as well as parents' level of education and income level. Trusty (2002) notes that African American and Hispanic male students from higher socioeconomic backgrounds pursue science and math majors in college at a higher rate than those from lower socioeconomic backgrounds, but females did not display the same differential rate of participation between race and socioeconomic status. Parents' level of education has had an inconsistent affect on a student's choice of major in college, with one researcher finding that only African American male students were impacted positively according to their mother's level of education (Maple & Stage, 1991). The same authors found that locus of control did not impact a student's major choice for African American or white students but that the number of math and science courses taken prior to college impacted both races. Important differences within and between gender and racial categories exist within many of these findings, including different preferences for and persistence in specific types of STEM majors (Hanson, 2004; Oakes, 1990; St. John, Hu, Simmons, Carter & Weber, 2004; Trusty, 2002).

[1] A review of literature on women's departure from the STEM fields highlights a number of plausible explanations which recognize individual, institutional, and societal factors, including differential academic preparation as compared to men, girls' negative experiences with science, the lack of female role models in scientific fields, pedagogy which benefits males, and differences in how boys and girls are socialized (Blickenstaff, 2005). Many of these are also applicable to explaining the underrepresentation of racial and ethnic minorities. Socialization of individual's roles in society, role models, the climate of university departments and workplaces, culture of STEM, and even time-context considerations are now accepted as areas worthy of investigation into explaining women and minorities' departure from STEM at various points in the pipeline.

Researchers have offered various explanations for the continued underrepresentation—and by extension educational and social inequities—in the STEM fields. Entry into the STEM pipeline at the beginning is of vital importance, as the process of entering a STEM-related occupation starts as early as elementary and secondary school, continues through high school, and into college. Individuals who deviate from the STEM pipeline—by individual choice or other factors—will encounter great difficulty in re-entering the pipeline at a later point in time, or may never return (Elliott, Strenta, Adair, Matier & Scott, 1996). This is due to the fact that preparing to enter into STEM majors and occupations is a sequential and largely linear process given the prerequisites that are required to advance in the sciences and to continue in the STEM pipeline from year-to-year. Declaring a STEM major early in college is critical to minimizing additional time, funds, and opportunity costs spent in pursuing the degree "because the prerequisites for engineering coursework increase the 'cost' to switch into engineering for students who lack these courses" (Frehill, 1997, p. 228).

Although white and Asian males are well-represented in the STEM fields, African Americans are most likely than any other race/ethnicity group to major in science- and math-related fields (Staniec, 2004; Trusty, 2002). In fact, "after controlling for other factors that affect major choice, neither all females nor all minorities are, in fact, underrepresented" (Staniec, 2004, p. 556). In a study of three cohorts of college students at a small liberal arts college, "controlling for these differences [demographics, family influences, academic preparation, academic self-efficacy, and political views], we can see that males and females are just as likely to choose a non-science major over a science major" (Porter & Umbach, 2006, p. 441). This finding offers a reminder that factors affecting the choice of non-STEM majors are just as important to investigate as factors that affect the choice of STEM majors. Important differences exist within the gender categories of who pursues a STEM major. Asian women are more likely than other women to major in STEM fields, as “once Asian women make it to college, they appear to be less affected by the gender-based segregation of college majors” (Song & Glick, 2004, p. 1413). Within men, Asians are most likely to pursue math and science majors compared to other racial and ethnic groups (Trusty, 2002).

Trusty (2002) notes that African American and Hispanic male students from higher socioeconomic backgrounds pursue science and math majors in college at a higher rate than those from lower socioeconomic backgrounds, but females did not display the same differential rate of participation between race and socioeconomic status. Parents' level of education has had inconsistent affect on a student's choice of major in college, with one researcher finding that only African American male students were impacted positively according to their mother's level of education (Maple & Stage, 1991). These are just a few of the many factors investigated in research on differential participation in the STEM fields. What continues to be evident in the dearth of research on reasons for women and minority’s underrepresentation in the STEM fields is that the factors and explanations identified thus far “remain unclear and in some cases quite controversial” (Rosenbloom et al., in press, p. 2).

The sociology of education emphasizes the importance of parents’ level of education on the educational and occupational attainment of their children, beginning with the status attainment model presented by Blau & Duncan (1967), which investigated the impact of fathers’ educational and occupational attainment on sons’ educational and occupational attainment. Today, parental factors that impact an individual’s choice of major extends beyond parents’ level of education. Parents who are employed in STEM-related fields have a positive impact on their children (male and female) choosing to major in STEM (Leslie, McClure, Oaxaca, 1998), with the greatest impact being on Hispanic males and Black males (Leslie & Oaxaca, 1998). A study of students at historically Black colleges and universities (HBCUs) who persisted in STEM indicated that they were positively impacted in their choice to pursue a STEM major due to their parent's education and careers in scientific fields (Fleming, Engerman & Griffin, 2005).

Staniec (2004) found that females who were raised in single-parent homes were less likely to choose a STEM major than those raised in two-parent households. Students who originated from higher socioeconomic backgrounds were more likely to major in STEM fields, with the largest effects found for Hispanic men. Trusty (2002) notes that African American and Hispanic male students from higher socioeconomic backgrounds pursue science and math majors in college at a higher rate than those from lower socioeconomic backgrounds, but females did not display the same differential rate of participation between race and socioeconomic status. Overall, African American women are about twice as likely as white women to declare a STEM major (Hanson, 2004).

Academic preparation for entrance to a STEM major can be measured by courses taken in high school, performance in those courses (as measured by grades), and performance on standardized college entrance exams (as measured by test scores). A high level of academic preparation on each of these measures is often typical of students in STEM majors as compared to other majors (Levine & Wycokoff, 1991). This can be a function of both admissions requirements to STEM majors, and a student's level of academic preparation may be correlated with choosing a major based on related future career earnings (Song & Glick, 2004). Overall, "taking more science courses in high school, having higher self-ratings relative to mathematics and scientific abilities, and having higher indices of family background not only enhances the likelihood of the selection of a quantitative field of study, but also enhances the likelihood of selecting engineering or the physical sciences as a major" (Ethington, 2001, p. 359), suggesting that different measures of academic preparation work collectively to increase the probability of declaring a STEM major. A students' choice of STEM major has been found to be positively impacted by the number of courses the student completed in high school in similar disciplines, with the number of math and science courses taken prior to college having a positive impact on whites and African Americans (Maple & Stage, 1991).

Several studies have found that higher preparation for women in math and science results in a greater probability of declaring a STEM major, specifically “taking the most academically intensive math courses—trigonometry, pre-calculus, calculus” (Trusty, 2002, p. 471), and that scoring high on the SAT (Turner & Bowen, 1999). Increasing the level of academic preparation of women has been suggested as a way to increase their participation in these fields in college, however, results from two studies suggest that other interventions will be necessary as well. Frehill (1997) cautions that “increasing the number of math and science courses that girls take in high school would increase the proportion of women who choose engineering by a modest amount” (p. 242), while Turner and Bowen (1999) found that gender “differences in SAT scores account for less than half of the total gender gap” in STEM fields (p. 305). These findings suggest that women who choose to declare non-STEM majors are making choices based on a combination of factors, with academic preparation being only one of many. Men may choose STEM fields at a greater rate than women as a result of “the joint product of variations in SAT scores (higher math scores for the men) and the relatively stronger preferences among men for these fields, though the relative magnitudes of these effects are not at all equal” (Turner & Bowen, 1999, p. 304).

Research Objectives

This study will estimate the effect of individual and institutional selection factors on underrepresented students' enrollment in STEM fields in comparison to that of their well-represented counterparts. By specifically modeling initial major choice, this study will provide a more accurate picture of the matriculation decisions of underrepresented students in STEM fields during a critical period in postsecondary education. The results of this research will also contribute to institutional effectiveness by identifying possible interventions that may satisfy both educational and diversity goals. The following research questions will be examined:

1. Based on their pre-college academic qualifications, do more qualified undergraduate women, minorities, or low-income students opt out of STEM programs in favor of non-STEM programs, as compared to students from traditionally well-represented groups?

2. How might patterns of students opting in 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, but for this study, only information from the first year is used. Information on students' social backgrounds, pre-college academic qualifications and type and amount of financial aid received, as well as institutional measures, such as tuition differences for in-state and out-of-state residents, is 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. Full information was available on 10,880 students; mainly due to mother and father's education, which came from the Free Application for Federal Student Aid (FAFSA) form. Thus, only those who completed a FAFSA were used in the nested logistic regression analysis.[2]

[2] A comparison of FAFSA and non-FAFSA completers was conducted to determine whether there was any systematic bias due to the presence of the former and not the latter. Female, black and resident students were more likely to complete a FAFSA, while white and those with higher SAT score were less likely.

Methodology

A combination of quantitative methods and statistical models are used in an attempt to answer the research questions posed in this study. The first research question—who opts into STEM fields—will be addressed using both descriptive statistics and nested logistic regression (i.e., conditional decision-tree) models with socio-demographic characteristics, pre-college academic qualifications as measured by SAT scores,[3] and financial attributes (e.g., amount of financial aid received) included as explanatory variables.

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. Details of the estimation strategy are provided below.

Estimation Strategy

To estimate students' likelihood of entering a STEM major from a set of alternative majors, a nested logistic regression model will be used. The nested logistic regression requires the data to be organized as pairwise combinations of students, i, and unique combinations of majors, J. For the sake of simplicity, the initial major choice set is restricted to four general programs of study:

[3] ACT scores were converted to SAT scores to allow for ease of comparison of students' standardized test scores. Other measures of pre-college academic qualifications such as high school GPA or specific courses taken in high school are not included in the dataset.

Science & Engineering, Agricultural & Biological Science, Health & Psychology, and Non-STEM. Nested logistic regression models relax the assumption of independently distributed errors and the independence of irrelevant alternatives inherent in conditional logistic regression models by clustering selected alternatives into hierarchical "nests" (Greene, 2008). For this study, the four general programs of study comprise the first nest at the top of hierarchy, and specific majors that share common attributes (tuition and fee charge by resident status) comprise the second (or bottom) nest. In all, there are 8 unique combinations of majors.[4]

The estimation is based on students choosing major j at institution Q based on their individual characteristics, which are contained in vector X and attributes of the institution. These factors affect students' demand for one of the four majors listed above. Students select a particular major in their first year that maximizes their utility, $U(Y_j, X_i)$. Estimating this utility is done via a linear function of student characteristics

$$U(Q_j, X_i) = \beta_1 Z_{ij1} + \beta_2 Z_{ij2} + \ldots + \beta_k Z_{ijk} + \varepsilon_{ij}$$

where β is a vector of parameters, Z_{ij} are the variables that affect utility, k is the total number of variables in the model, and ε_{ij} is idiosyncratic error. Z may include variables that describe the elements of Y or interact with Y and X to form match-specific measures.

Discussion of Results

The results from the simple descriptive analysis and the nested logistic regression—shown in Tables 1 to 5—are discussed below.

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

[4] The distribution of the 8 combinations is shown in Table 5.

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.[5] Male and female representation within racial and 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 some college or higher.[6]

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). Discussion of cost, financial aid, and net price by first major declared appear below.

First major declared

Students' major field of choice the first semester of college (fall 1999) was examined (see Table 2). Overall, 24 percent of students began their undergraduate studies in Science and Engineering fields, 9 percent in the Agricultural and Biological Sciences, 11 percent in Health and Psychology, and 56 percent in Non-STEM fields. While women's underrepresentation in the high-profile, high-status STEM fields such as engineering is well-documented, using this expanded taxonomy of majors reveals a different picture in terms of women's participation in science-oriented majors at the undergraduate level. If only male (36 percent) and female (11 percent) participation in

---

[5] 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).
[6] Slightly more than one-quarter of father and mother's highest level of education each is missing from the dataset.

Science and Engineering fields are compared, it appears that very few women initially enroll in the sciences. However, by also investigating enrollment in other scientific-based fields, such as the Agricultural and Biological Sciences, and Health and Psychology fields, more females are enrolled in each of these categories as compared to males (10 percent versus 8 percent for Agriculture and Biological Sciences, and 18 percent versus 5 percent for Health and Psychology, respectively). Combining these three STEM categories—all of which are science-oriented although to varying degrees—50 percent of men and 38 percent of women are enrolled in STEM majors. Although women are still participating in these fields at lower rates than men, the overall participation of women in science-oriented fields (by including a broader and more nuanced definition of STEM) increases.

The differentiation of STEM fields according to this classification also reveals increase participation for Blacks and Hispanics. If only Science and Engineering fields are examined, only 19 percent of Blacks males and 11 percent of Black females enroll in these majors. Using the expanded taxonomy, these numbers increase to 31 percent and 36 percent, respectively. Likewise, 29 percent of Hispanic males and 9 percent of Hispanic females initially choose a Science and Engineering major. When examining their participation across additional science-based fields, their enrollments increase to 38 percent for Hispanic males and 36 percent for Hispanic females.

Financial aid

Financial aid information is available for students who filed a FAFSA form, which comprise approximately three-quarters of the students in the 1999 cohort (see Table 3). Of those who completed a FAFSA form, 20 percent received a Pell grant, signifying low-income status. The net price, which is calculated from the tuition and fee charges for the first year of attendance minus any grants[7], averaged approximately $10,500 for Science and Engineering majors, $9,500 for Agricultural and Biological Science majors, $9,300 for Health and Psychology majors, and $9,700 for Non-STEM majors. Women across all four major categories have slightly lower net prices as compared to their male counterparts. Asian males in the Science and Engineering fields have the highest average net prices of all groups within this field ($11,261), which is noticeably higher than the net price of Blacks and Hispanics enrolled in the same majors. Black females enrolled in the Agricultural and Biological Sciences have the lowest average net price of any group across each of the four categories ($7,108) followed by Black females enrolled in the Science and Engineering fields ($7,142).

Nested logistic regression

Drawing from the descriptive analysis, the nested logistic regression allows for the key factors mentioned above to be estimated. This analysis addresses the second research question; namely, are the factors that affect opting into STEM consistent across other majors? The nested logistic regression results generally confirm the earlier findings, but also highlight some important differences that the descriptive analysis was unable to detect (see Table 4).

As noted earlier, females and non-Asian minorities are generally less likely to enroll in Science and Engineering than their white and Asian male counterparts. The results from the nested logistic regression, however, reveal a more complex picture. At these three universities, for example, females are much less likely to enroll in Science and Engineering majors than their male peers, but are more likely to enroll in Health and Psychology, *ceteris paribus*. These findings suggest that the STEM pipeline is not entirely closed to females, but instead may be directed toward less prestigious, but still important, science majors.

[7] Grants include Pell Grant, Supplemental Education Opportunity Grant (SEOG), state grants, institutional grants, and other aid. Loans and work-study are excluded from this calculation.

In terms of differences between racial and ethnic groups, Blacks and Hispanics are less likely to enroll in Science and Engineering majors, as well as in Agricultural and Biological Sciences majors. Asians are more likely to enroll in the Science and Engineering majors as compared to their other racial and ethnic minorities. Interestingly, students who are in-state residents at each respective campus are less likely to enroll in any of the three STEM categories of majors (Science and Engineering, Agricultural and Biological Sciences, and Health and Psychology). This suggests that non-residents are actively and competitively recruited to enter STEM fields across each of the three STEM categories. Low-income students, as measured by receiving a Pell Grant, are less likely to pursue a Science and Engineering major or a Health and Psychology major. Choosing a Science and Engineering major was also positively affected by having a father or mother with more than a college degree. However, choosing a major in Health and Psychology was negatively impacted by the father having at least some college or higher level of education.

The predicted probabilities of selecting one of the 8 alternatives from the choice set are shown in Table 5. Shaded rows indicate results for out-of-state students. Comparing predicted to actual distributions, the model fits the data for STEM majors, broadly speaking, quite well. For instance, 18 percent of first-time, full-time, in-state undergraduates enrolled in a Science and Engineering major. The nested logistic regression predicted 20 percent of these students to do so. The model also closely predicts the actual enrollments of students in the Agricultural and Biological Sciences, as well as Health and Psychology. Interestingly, the model predicts fewer in-state resident students to enroll (38 percent versus 45 percent), and more out-of-state resident students (14 percent versus 9 percent) to enroll in Non-STEM fields.

Policy and Program Implications

This study makes several contributions. First, it contributes to the collective understanding of representation of women and minorities in STEM fields at the undergraduate level, as well as factors that affect major field choice. A better understanding of the key factors that affect underrepresented students' matriculation in the STEM fields, such as SAT score of the program sought and the tuition and fees charged as demonstrated by this study, will help policymakers and postsecondary administrators design programs to promote enrollment so that students can benefit more fully from entering undergraduate programs that are associated with earning higher incomes, experiencing greater social mobility, and benefiting from enhanced professional opportunities. As May and Chubin (2003) contend that the previous underrepresentation by minorities in the STEM fields is a repairable problem through program and policy improvements, the research findings presented here can be used to inform institutional-based recruitment interventions.

In addition, the taxonomy used in this research that includes additional science-oriented majors that are traditionally excluded from the literature on STEM fields demonstrates the importance of using a more inclusive definition of what comprises "STEM." Although women, non-Asian minorities, and low-income students remain underrepresented in high-profile, high-prestige STEM fields as compared to their white and Asian male counterparts, their participation rates in the sciences increases when the fields of Agricultural and Biological Sciences, Health, and Psychology majors are included in the measure of STEM participation. This finding challenges notions of disinterest or disengagement by underrepresented students in scientific fields at the undergraduate level.

This broad definition of STEM can be used by universities in their recruitment efforts of underrepresented students. By emphasizing participation across a broader swath of scientific programs on a particular campus instead of just focusing on the high-prestige STEM fields, prospective students may be more encouraged to attend the institution. In this sense, universities should examine their scientific community across all science and math-based majors, and highlight the participation rates and achievements of underrepresented students in those fields. Although the finding of increased participation in the sciences is encouraging, research should continue to investigate reasons for underrepresentation in the Science and Engineering fields, as well as reasons for participation in the Agricultural and Biological Sciences, Health and Psychology fields by members of these groups.

The results also suggest that financial aid policies, i.e., offering grants, have been somewhat successful as a recruitment device to attracting underrepresented students in STEM fields. In order for underrepresented students to continue to seek higher-cost STEM fields, then existing levels of financial assistance need to persist and, if possible, be expanded. Ultimately, universities can use financial aid to target these students and reduce the substantial cost to entry barriers that exist in these STEM fields

Lastly, the study also makes a methodological contribution through the use of a nested logistic regression. The nested framework is uniquely suited to handle interrelated choices and allow a relaxation of the IIA (Independence of Irrelevant Alternatives) property.

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. The data also lacks variables that could provide more insight into students' pre-college academic qualifications such as their high school grade point average, high school transcript information, or non-cognitive measures. In addition, the use of standardized test scores has somewhat limited utility as an indicator of academic preparation. Furthermore, the universities' admission process considers other factors that are not included in the dataset, such as high school coursework requirements, application essays, extracurricular activities, service, and work experience.[8] Finally, important differences within gender and within racial and ethnic groups cannot be examined due to the number of observations of these groups in the dataset.

Some of these limitations will be addressed in future research. The next phase of the research will merge the data used in this paper with data from the U.S. Department of Education's Common Core Data (CCD) and the Office of Civil Rights (OCR) to provide information on the high schools students' attended, including the number of AP math and science courses offered.[9]

Given that this study only examines the initial major field of choice for students, it is also pertinent to examine persistence and degree attainment in future studies. The dataset follows students for a period of six years, providing semester-by-semester major information, allowing for persistence and completion patterns to be investigated. Of particular interest will also be following students who switch in and out of the various STEM majors and investigating the factors that contribute to these movements.

Lastly, it is important to note that appearing alongside the call for increased educational equity and access to postsecondary education for underrepresented students is the call to strengthen our nation's globally competitive workforce. Former U.S. Education Secretary Margaret Spellings' Commission on the Future of Higher Education, which released a report based on a year-long

[8] Applications to specific majors such as those classified as visual and performing arts may also require portfolios and/or auditions.
[9] Merging these datasets will reduce the number of observations given that the OCR data is based on a stratified random sample of public schools.

review of the status of U.S. higher education in fall 2006, argues for the need for more American-born scientists in order to strengthen the nation's workforce and global competitiveness (U.S. Department of Education, 2006). Thus, in response to this appeal, and to better understand the preparation of a skilled workforce, it is important to also consider the persistence and attainment patterns of those who enter the STEM education pipeline and the impact (and responsibility) of large, research-intensive, public universities in educating undergraduates in these fields. Persistence and degree attainment in the STEM fields will be examined in future studies to determine the educational outcomes of students according to their initial major choice.

References

Blau, P.M., & Duncan, O.D. (1967). *The American occupational structure*. New York: Wiley.

Blickenstaff, J. C. (2005). Women and science careers: leaky pipeline or gender filter? *Gender & Education, 17*(4), 369-386.

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

Elliott, 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.

Fleming, L., Engerman, K. & Griffin, A. (2005). *Persistence in engineering education: Experiences of first year students at a historically black university*. Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition. June 12-15, 2005, Portland, OR. Retrieved July 2, 2008, from http://www.asee.org/acPapers/2005-1786_Final.pdf

Frehill, L. M. (1997). Education and occupational sex segregation: The Decision to Major in Engineering. *The Sociological Quarterly, 38*(2), 225–249.

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

Greene, W.H. (2008). *Econometric analysis* (6th ed.). MacMillan: New York.

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.

Leslie, L. L., McClure, G. T., & Oaxaca, R. L. (1998). Women and Minorities in Science and Engineering: A Life Sequence Analysis. *The Journal of Higher Education, 69*(3), 239-276.

Leslie, L.L., & Oaxaca, R.L. (1998). Women and minorities in higher education. In J.C. Smart (Ed.). , *Higher education: Handbook of theory and research*, Vol. 13, New York: Agathon Press, 304-352.

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

Maple, S.A., & Stage, F.K. (1991). Influences on the choice of math/science major by gender and ethnicity. *American Educational Research Journal, 28*(1), 37-60.

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.

Porter, S. R., & Umbach, P. D. (2006). College major choice: An analysis of person–environment fit. *Research in Higher Education, 47*(4), 429-449.

Rosenbloom, J.L., Ash, R.A., Dupont, B., & Coder, L. (in press). *Why are there so few women in information technology? Assessing the role of personality in career choices*. Journal of Economic Psychology.

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

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

Song, C., & Glick, J. E. (2004). College Attendance and Choice of College Majors Among Asian-American Students. *Social Science Quarterly (Blackwell Publishing Limited), 85*(5), 1401-1421.

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.

Staniec, J. F. O. (2004). The effects of race, sex, and the expected returns on the choice of college major. *Eastern Economic Journal, 30*(4), 549-562.

Trusty, J. (2002). Effects of High School Course-Taking and Other Variables on Choice of Science and Mathematics College Majors. *Journal of Counseling & Development, 80*(4), 464.

Turner, S. E., & Bowen, W. G. (1999). Choice of Major: The Changing (Unchanging) Gender Gap. *Industrial and Labor Relations Review, 52*(2), 289-313.

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. Percentage distribution of initial major choice of first-time freshmen by gender and race, 1999

		White		Black		Hispanic		Asian		Other		Total	
Initial major		**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Science &		2,482	674	61	47	87	24	315	92	73	16	3,018	853
Engineering	Row %	36.0	10.3	19.1	10.9	28.8	8.6	49.5	18.5	41.0	11.5	36.2	10.8
	Column %	82.2	79.0	2.0	5.5	2.9	2.8	10.4	10.8	2.4	1.9	100.0	100.0
Agriculture & Biological		547	659	19	38	18	24	61	56	17	10	662	787
	Row %	7.9	10.1	6.0	8.8	6.0	8.6	9.6	11.2	9.6	7.2	8.0	10.0
	Column %	82.6	83.7	2.9	4.8	2.7	3.1	9.2	7.1	2.6	1.3	100.0	100.0
Health &		377	1,167	20	72	10	51	27	68	6	19	440	1,377
Psychology	Row %	5.5	17.8	6.3	16.7	3.3	18.3	4.3	13.7	3.4	13.7	5.3	17.5
	Column %	85.7	84.8	4.6	5.2	2.3	3.7	6.1	4.9	1.4	1.4	100.0	100.0
Non-STEM		3,490	4,044	219	275	187	180	233	282	82	94	4,211	4,875
	Row %	50.6	61.8	68.7	63.7	61.9	64.5	36.6	56.6	46.1	67.6	50.6	61.8
	Column %	82.9	83.0	5.2	5.6	4.4	3.7	5.5	5.8	2.0	1.9	100.0	100.0
Total		6,896	6,544	319	432	302	279	636	498	178	139	8,331	7,892
	Row %	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Column %	82.8	82.9	3.8	5.5	3.6	3.5	7.6	6.3	2.1	1.8	100.0	100.0

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

Table 3. Average cost, aid, loan, and net price amounts of first-time freshmen by initial major, gender and race/ethnicity, 1999

		Total costs		Total aid		Total loans		Net price	
		Male	Female	Male	Female	Male	Female	Male	Female
Science & Engineering	White	$13,393	$13,705	$6,013	$6,223	$3,457	$2,959	$10,896	$10,529
	Black	$13,334	$12,957	$10,114	$7,807	$4,135	$1,949	$7,668	$7,142
	Hispanic	$12,876	$14,246	$8,229	$8,531	$2,456	$2,149	$7,402	$8,016
	Asian	$14,571	$14,253	$6,483	$7,152	$2,946	$3,262	$11,261	$10,729
	Other	$13,721	$13,814	$7,592	$11,414	$3,511	$6,436	$8,557	$8,398
	Total	$13,508	$13,741	$6,272	$6,565	$3,390	$2,949	$10,679	$10,229
Agriculture & Biological	White	$11,822	$11,782	$5,969	$5,601	$3,625	$2,910	$9,752	$9,418
	Black	$14,989	$12,918	$12,066	$9,271	$5,958	$3,240	$9,183	$7,108
	Hispanic	$13,485	$13,642	$8,522	$8,460	$4,222	$3,372	$9,715	$9,072
	Asian	$13,699	$12,691	$5,893	$6,468	$3,189	$3,494	$11,288	$10,303
	Other	$13,711	$11,156	$5,612	$4,171	$3,859	$2,246	$12,242	$8,554
	Total	$12,180	$11,950	$6,264	$5,973	$3,701	$2,976	$9,929	$9,308
Health & Psychology	White	$11,908	$11,953	$5,505	$6,031	$3,034	$3,355	$9,613	$9,541
	Black	$13,325	$12,456	$9,296	$8,811	$4,050	$3,744	$8,472	$7,945
	Hispanic	$13,846	$13,399	$9,139	$9,331	$2,384	$3,648	$7,597	$8,359
	Asian	$13,630	$12,755	$9,704	$6,574	$6,032	$2,941	$10,055	$9,201
	Other	$10,585	$12,989	$5,896	$5,498	$950	$2,964	$5,639	$10,614
	Total	$12,104	$12,086	$6,054	$6,362	$3,215	$3,366	$9,458	$9,391
Non-STEM	White	$12,318	$12,267	$5,761	$5,826	$3,552	$3,292	$10,135	$9,862
	Black	$13,602	$12,929	$10,406	$9,366	$3,347	$3,300	$6,811	$7,511
	Hispanic	$13,260	$13,065	$7,574	$7,587	$3,015	$3,161	$9,090	$8,874
	Asian	$13,908	$13,232	$6,362	$7,059	$3,193	$3,016	$10,757	$9,370
	Other	$13,062	$12,768	$7,955	$7,038	$4,412	$3,801	$9,287	$9,386
	Total	$12,529	$12,399	$6,243	$6,258	$3,505	$3,282	$9,875	$9,608

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

Table 4. Nested logit regression results of initial major choice

Second level equation

	Major choice [8 alternatives]
R's SAT score - Avg. SAT score	**-0.435**
	(0.08)
Net price	**0.759**
	(0.04)

First level equation [<u>Ref</u>: *Non-STEM major*]

	Science & Engineering	Agriculture	Health
Female	**-1.455**	**-0.159**	**0.741**
	(0.05)	(0.06)	(0.06)
Black	**-0.544**	**-0.453**	-0.119
	(0.13)	(0.16)	(0.13)
Hispanic	**-0.301**	**-0.432**	-0.210
	(0.13)	(0.18)	(0.16)
Asian	**0.653**	0.047	0.047
	(0.09)	(0.14)	(0.14)
Other race	0.022	0.010	-0.378
	(0.17)	(0.25)	(0.25)
Resident	**-0.557**	**-0.182**	**-0.280**
	(0.05)	(0.09)	(0.08)
Received Pell Grant	**-0.267**	-0.155	**-0.171**
	(0.06)	(0.08)	(0.07)
Father's education level:	**0.130**	-0.121	**-0.180**
At least some college	(0.05)	(0.07)	(0.06)
Mother's education level:	**0.133**	0.011	**-0.137**
At least some college	(0.05)	(0.07)	(0.06)
Number of observations		87,040	
Number of cases		10,880	
Log likelihood		-18072.9	

Note: Statistically significant (p<0.05) are shown in bold.

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

Table 5. Model fit by type of model estimated and initial major

	Actual		Predicted	
	Cases	Pct	Cases	Pct
Science & Engineering	1987	18.3	2127	19.5
Agriculture	862	7.9	927	8.5
Health	1115	10.3	1217	11.2
Non-STEM	4847	44.6	4157	38.2
Science & Engineering	726	6.7	616	5.7
Agriculture	127	1.2	108	1.0
Health	215	2.0	181	1.7
Non-STEM	1001	9.2	1548	14.2
	n	10,880	N	87,040

Note: Estimates shown in grey are for non-residents.

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