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ABSTRACT

This study examined factors predicting the enrollment of men and women in science, math, and engineering (SME) graduate programs among those who had earned SME Bachelor's degrees. The data, which covered a 9-year period: 1985, 1989 (4-year follow-up), and 1994 (9-year follow-up), was drawn from the Cooperative Institutional Research program, a national longitudinal study of 12,000 students from the 1985 freshman class. Analysis were limited to 2,563 college students who had earned an SME bachelor's degree, found that students from engineering and the physical sciences who were most likely to enroll in SME graduate programs, followed by students from the biological and mathematics/computer sciences. While there were no gender differences in the likelihood of enrollment in SME graduate programs among students from the biological sciences and engineering, men from the physical and mathematics/computer sciences were more likely than women in those field to pursue SME graduate education. Using regression analysis, it was determined that the strongest predictor of women's enrollment in SME graduate programs was having a precollege interest in making a theoretical contribution to science. Women's pursuit of SME graduate degrees was also positively affected by having a mother who was either a research scientist or college teacher. Two appendixes provide variable definitions and coding schemes and factor scales. (Contains 41 references.) (MDM)

The impact of college on post-college commitment to science careers: Gender differences in a nine-year follow-up of college freshmen

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In the past thirty years, women have increased their share of science, math, and engineering (SME)[1] bachelor's, master's, and doctoral degrees by 106 percent, 150 percent, and 267 percent, respectively (National Science Foundation, 1995). Although the gender gap has certainly narrowed in these past decades, women have not yet achieved parity. Currently, women are underrepresented among SME degree recipients at all levels, particularly at the graduate level, earning 33 percent of bachelor's degrees, 25 percent of master's degrees, and 22 percent of doctoral degrees (calculated from NSF, 1995 data).

Numerous studies have addressed women's underrepresentation in science, providing many answers to questions such as: Why are young girls less interested in science than boys are? What factors discourage women from taking more math and science courses in high school? What types of women choose to major in SME fields in college? And among them, who persists towards the bachelor's degree?

Many fewer studies, however, address the question of persistence in science <u>after</u> the undergraduate years. In some ways, this question is a lot more difficult to answer. Certainly, a student with a bachelor's degree in physics who ultimately earns a physics doctorate can be considered an SME persister. And an engineer turned artist can probably be considered a non-persister in SME. However, what about the undergraduate math major who becomes a junior high school algebra teacher? Or the biology major who becomes a heart surgeon? Certainly these individuals have not abandoned SME fields entirely. For this reason, any study of persistence in SME beyond the undergraduate years must be particularly careful with definitions.

This study considers persistence in SME as the continued pursuit of a career in scientific research. This definition purposefully focuses on the development of the talent pool of academic scientists and engineers and other scientific researchers. More specifically, this study focuses on how

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[1] SME fields include engineering; physical sciences; earth, atmospheric, and ocean sciences; mathematics and computer science; and biological science.

the post-baccalaureate pursuit of SME research careers differs between men and women. Although there is no consensus as to whether there is an economic "need" for more research scientists (National Academy of Sciences, 1995), certainly the development of this talent pool should be mindful of equity.

Background: Predictors of Science Persistence

K-12 preparation in mathematics and science. Women's participation in science declines steadily throughout the educational process (Oakes, 1990b). As early as elementary school, girls and boys exhibit relatively equal math and science abilities, yet girls express less interest in these fields. By junior high school, performance of girls and boys is still comparable within math and science courses, but girls take fewer of these courses than boys do. By high school, women take significantly fewer courses in math and science than do men (Dearman & Plisko, 1981; Frieze & Hanusa, 1984; Matyas, 1985a, 1992).

Since math and science courses are typically prerequisites for college science programs, lower levels of preparation inherently preclude many women from pursuing scientific fields in college (Oakes, 1990a, 1990b; Brush, 1985; Vetter, 1989). Studies have shown consistently that the number of high school math and science courses taken by women is strongly related to women's choice of a scientific major in college (Ethington & Wolfle, 1988; Peng & Jaffe, 1979; Ware & Lee, 1988), as well as their performance in math and science courses during college (DeBoer, 1984).

Confidence in mathematical and scientific abilities. Women's interest in science is also hindered by a persistent relative lack of mathematical and scientific self-confidence. Math self-confidence is the most influential predictor of math test performance, which, in turn, predicts women's entry into science fields (Ethington, 1988; Grandy, 1987; Matyas, 1985b; Peng & Jaffe, 1979; Ware, Steckler & Lesserman, 1985). However, the fact is that women at all levels express lower levels of mathematical and scientific confidence than do men (Frieze & Hanusa, 1984; Humphreys, 1984; MacCorquodale, 1984; Matyas, 1985a; Sax, 1994a; Sonnert, 1995).

Parental influence. Parents also play a critical role in influencing women's course of study and eventual careers. Ethington and Wolfle (1988) found that, in general, parents tend to discourage their daughters from quantitative fields of study. Daughters of more highly-educated parents, however, are more likely to choose a science major in college (Ware, Steckler, & Lesserman, 1985) and ultimately to choose sex-atypical careers (Gruca, Ethington, & Pascarella, 1988).

Family/career interface. From an early age, women are conditioned to believe that they must choose between family and career—particularly in the sciences (Frieze & Hanusa, 1984; Lips, 1992; Peng & Jaffe, 1979; Seymour & Hewitt, 1994; Sonnert, 1995). The perception that a career in science is incompatible with raising a family turns many women away from the pursuit of scientific fields. Indeed, Ware and Lee (1988) found that women who place a high priority on personal life and family responsibilities are less likely than other women to major in science during college. Interestingly, such perceptions have persisted even though research has consistently shown that marriage and children do not have a negative effect on women's science career attainment and productivity, except during child bearing and early child rearing years (Matyas, 1985b).

Undergraduate education. Those women who do choose to major in an SME field in college face further challenges. Teaching practices in the sciences alienate many students, and women in particular, by encouraging competition, reinforcing the notion of science as "unconnected" to social concerns, and portraying science careers as lonely and excessively demanding (Rosser, 1990; Tobias, 1992). In a study of undergraduates, students noted poor pedagogy and inadequate advising as concerns in science. Faculty in the sciences were seen as unapproachable, preoccupied with research, and lacking motivation to teach well (Seymour and Hewitt, 1994). Science faculty are also much less likely to employ teaching styles preferred by women, such as class discussions, cooperative learning techniques, and student selected topics (Milem & Astin, 1994). Instead, science faculty are more likely to rely on the traditional lecture format and are more likely to grade on a curve, a practice which inherently promotes competition among students. While science curriculum and pedagogy may also alienate a number of men, Rosser (1990) suggests that women will be particularly discouraged by the non-"female-friendly" teaching practices in the sciences.

Post-college science persistence. Little is known about the factors affecting women's and men's persistence in science after the undergraduate years. Using data from the first four years of the nine-year data set employed in this study, Sax (1994b) explored the persistence of science career aspirations among men and women who as freshmen indicated an interest in science. That study showed that in addition to traditional predictors of science persistence (e.g., greater science preparation and a stronger commitment to scientific inquiry), persistence in science is also determined by students' desires and motivations with respect to their intended career. It was in this realm that interesting gender differences emerged, such that men's career decisions were more often driven by expected monetary or status rewards, while the career decisions of women were driven by the "social good" of their career choice. Although the Sax (1994b) study examined students' intentions to pursue scientific careers after the undergraduate years, the four-year time frame did not allow for a study of which students actually engaged in post-college behaviors that would prepare them for science careers (e.g., enrollment in SME graduate programs).

The issue of post-college commitment to science was addressed recently by Rayman and Brett (1995), who monitored the early career paths of women who had earned bachelor's degrees in science at a women's college. While their study confirmed the importance of early math and science preparation, as well as advice and encouragement from significant others (e.g., parents, teachers), some surprising findings did emerge. Most notably, two of the most often cited predictors of science persistence—grades and self-esteem—did not predict persistence in science after the undergraduate years. The authors suggest that these findings may simply be a function of studying women attending a particular women's college.

While the Rayman and Brett study was an important first step in understanding women's post-college pursuit of science careers, its focus on students from a single women's college prevents an understanding of whether such findings would emerge across a diverse set of institutions. Further, by studying only women, we cannot know the extent to which personal and environmental influences on the pursuit of science careers may differ between men and women.

Objectives

This study aims to expand our understanding of women's pursuit of science careers by examining the factors predicting enrollment in SME graduate programs among men and women who have earned SME bachelor's degrees. Specifically, through the use of a recently completed longitudinal study of 12,000 students from the 1985 freshman class who were followed-up four and nine years after entering college, this study examines how SME graduate school enrollment is influenced by women's and men's backgrounds, pre-college educational experiences, as well as undergraduate environments and experiences. As noted by Hollenshead, Wenzel, Lazarus, & Nair (1996), longitudinal, multi-institutional studies on women enrolling in SME graduate programs have been noticeably absent from the research.

Methods

Data source and sample

Data are drawn from a national, longitudinal study of college students conducted at three time-points over a nine-year period: 1985, 1989, and 1994. These data were collected as part of the Cooperative Institutional Research Program (CIRP), which is sponsored by the American Council on Education and the Higher Education Research Institute (HERI) at the University of California, Los Angeles. The CIRP annually collects a broad array of student background information using the Student Information Form (SIF), and is designed to serve as a pretest for longitudinal assessments of the impact of college on students. Data for this study are drawn from the 1985 SIF administered to freshmen, the 1989 Follow-up Survey of 1985 Freshmen, and the 1994 Nine-Year Follow-up of 1985 Freshmen.

The freshman and follow-up surveys are ideally suited for science pipeline issues. First, the data are longitudinal, making it possible to measure student change and development directly rather than attempting to infer it from cross-sectional data. Secondly, these three datasets are multi-institutional. Collecting data from a diverse set of undergraduate institutions makes is possible to accurately assess institutional effects on student outcomes by representing a wide variation in environmental measures.

The Student Information Form. The Student Information Form (SIF) was distributed to campuses in the Spring and Summer of 1985 for distribution to college freshmen during orientation programs and in the first few weeks of fall classes. The 1985 SIF includes information on students' personal and demographic characteristics, high school experiences, expectations about college, as well as values, life goals, self-concepts, and career aspirations. A total of 279,985 students at 546 participating colleges and universities completed the SIF.

The 1989 Follow-up Survey. In 1989, HERI conducted a longitudinal follow-up of 1985 freshmen. The 1989 Follow-up Survey includes information on students' college experience, their perceptions of college, as well as post-tests of many of the items that appeared on the 1985 Freshman Survey. Responses were received from approximately 27,000 students from over 300 colleges and universities (see HERI, 1991). Funding for this follow-up was received from the National Science Foundation (NSF) and the Exxon Education Foundation. NSF support was specifically designed to support a national study of undergraduate science education (HERI, 1992; Sax 1994b). The present study examines those same undergraduates over a longer a period of time.

The 1994 Nine-Year Follow-up Survey. The Nine-Year Follow-up Survey provides information on graduate school and early career experiences, as well as post-test data on many of the attitudinal and behavioral items appearing on the 1985 and 1989 surveys. Funding for this follow-up was received from the Exxon Education Foundation and the Ford Foundation. The Nine-Year Follow-up sample includes 17,783 students (7,423 men and 10,360 women) who entered 224 undergraduate institutions in 1985. The present study draws from a database of students who completed all three questionnaires (1985, 1989, and 1994): 12,376 students (5,019 men and 7,357 women) at 209 institutions. Analyses are limited to the 2,563 students from that sample who earned a bachelor's degree in an SME field, since they comprise the most likely pool of candidates for enrollment in SME graduate programs. Table 1 displays the gender and undergraduate major distribution of this sample.

Research Methods

This study utilizes the "input-environment-outcome" (I-E-O) research model employed previously in a number of longitudinal studies (Astin & Panos, 1970; Astin, 1977, 1991, 1993; Sax, 1994a, 1994b, 1996). This methodological framework allows the researcher to examine the impact of various environments and experiences on individual outcomes, after controlling for pre-existing differences between individuals. In the present study, the I-E-O model will be used to analyze the impact of college on enrollment in SME graduate programs, controlling for students' pre-college (input) characteristics, such as previous math/science performance and interest in science.

Blocked stepwise linear regression analyses were conducted separately for male and female undergraduate science majors (using SPSS 6.1 for Windows) in order to explore which student background characteristics and undergraduate environments and experiences predict enrollment in SME graduate programs. Each block of independent variables is included in the temporal sequence in which it may have an effect on the dependent variable. Within each block, variables (significant at $p < .05$) enter the regression equation in a stepwise fashion. Although logistic regression is commonly used to analyze dichotomous dependent variables, such as enrollment in graduate school, linear stepwise regression was employed in the present study for two reasons. First, SPSS linear regression procedures allow for an examination of how regression coefficients change as each variable enters the equation, regardless of whether the variable actually enters the equation. Second, results of linear regression and logistic regression have been shown to be nearly identical so long as the distribution on the dependent variable is within the range of a .75/.25 split (Dey & Astin, 1993); the distribution on the dependent variable in the present study (enrollment in an SME graduate program) falls within that range.

Variables

The dependent variable used in this study is enrollment in an SME graduate program. SME programs include the following fields: biological sciences, engineering, physical sciences, and mathematical and computer sciences. Graduate enrollment information is based on students' self-reported current or most recent graduate/professional school and major on the 1994 nine-year follow-up survey.

In accordance with the I-E-O model, independent variables were blocked in the temporal sequence in which they may have an effect on enrollment in SME graduate programs: (1) student input characteristics, (2) pre-college major and career choices, (3) institutional characteristics, and (4) undergraduate experiences/perceptions. (See Appendix A for a complete list of variables and coding schemes.)

Input characteristics (blocks 1 and 2) include student background measures, such as parental income, and mother's and father's careers and educational levels. Inputs also include characteristics of the student before or at the point of college entry that may influence the post-college decision to enroll in an SME graduate program, such as SAT scores, high school grades, and high school science preparation. Input characteristics also include a set of six personality "typologies" based on students' self-concept, aspirations, personal goals, and behaviors: Scholar, Social Activist, Artist, Status Striver, Leader, and Hedonist. A second block of inputs includes the student's freshman major choice and intended career. This block can be considered a "bridge" between inputs and environments, since the initial choice of major and career is a characteristic of the student at the point of college entry, yet it also serves to define the type of environment to which the student is exposed during college.

Measures of the college environment (block 3) include structural characteristics of undergraduate institutions (size, type, and control) as well as characteristics of peer and faculty environments. Measures of the peer environment were created by calculating institutional mean responses to freshman survey variables, including peer science preparation and peer intellectual self-esteem. Measures of the science faculty environment, including research orientation and percent women, were created by aggregating science faculty responses to selected variables from the 1989-90 HERI Faculty Survey (see Astin, Korn, and Dey, 1991).

Undergraduate experiences and perceptions are included in block 4. These include measures of academic and nonacademic involvement, including time spent studying, interacting with students, and interacting with faculty. This block also includes posttests on selected freshman attitudes, levels of satisfaction with the undergraduate college, as well as reasons cited for pursuing one's intended career.

Results

Table 2 presents patterns of enrollment in graduate school for the pursuit of a master's degree or a Ph.D. for students from each of the four undergraduate science fields. Students from engineering and the physical sciences are most likely to enroll in SME graduate programs, followed by students from the biological and mathematical/computer sciences. While there are no gender differences in the likelihood of enrollment in SME graduate programs among students from the biological sciences and engineering, men from the physical and mathematical/computer sciences are more likely than women from those fields to pursue SME graduate education. The difference is most striking in math/computer sciences, with 30.0 percent of men pursuing SME graduate degrees, compared with 12.4 percent of women.

Of course, not all students enroll in SME graduate programs with the intent to earn a Ph.D. In fact, the data show that while the Ph.D. is commonly sought after by graduate students in the physical sciences (77.9 percent) and biological sciences (62.8), engineering graduate students are most likely to pursue the master's degree (56.9 percent); only 31.4 percent of engineering graduate students aspire to the Ph.D. In the mathematical/computer sciences, there is equal interest in master's and doctoral degrees (47.1 and 46.6 percent, respectively).

What specific graduate fields are chosen by SME undergraduates? Table 3 displays the graduate fields most commonly selected by SME undergraduates who attend graduate school (only percentages greater than 4.0 are displayed). Among undergraduate biological science majors, medicine is the most commonly selected graduate field, particularly among men (52.0 percent, compared with 36.8 percent of women). After medicine, 19.9 percent of men and 25.7 percent of women choose biological science graduate programs. Other graduate fields selected by undergraduate biological science majors include education (both men and women) and business (men only).

Among students earning bachelor's degrees in engineering, the overwhelming choice of graduate major is engineering (54.2 percent of women, 57.2 percent of men). Other graduate fields selected by engineering undergraduates include business, medicine, math/computer science, and law. There is essentially no gender difference in the choice of graduate major among undergraduate engineers, with the exception of the somewhat greater interest in math/computer sciences among women.

Physical science undergraduates, particularly women, select a more diverse range of graduate majors than other SME undergraduates. While 48.9 percent of men continue with the physical sciences in graduate school, only 28.6 percent of women do the same. Additional fields chosen by both men and women include: medicine, engineering, and business, with women more likely than men to select each of these fields. Women, but not men, select the following fields: biological sciences, pharmacy, and math/computer sciences. Interestingly, men from the physical sciences are more likely than women to enroll in education graduate programs.

Among students majoring in mathematical/computer sciences as undergraduates, the most popular graduate majors for both men and women are math/computer science, education, and business; engineering is selected only by men. What is perhaps most striking is that among math/computer science undergraduates, far more men than women go into math/computer science graduate programs (57.6 percent of men, 30.6 percent of women), whereas significantly more women than men choose the field of education (31.3 percent of women, 5.0 percent of men).

Regression analyses

Tables 4 and 5 provide a list of the variables that enter the separate regression equations for women and men. These tables include simple correlations, standardized regression coefficients (betas), and R^2 at the end of each block. In order to demonstrate how the regression coefficients change as different blocks of variables are controlled, betas are shown at two steps: (1) after controlling for all inputs (blocks 1 and 2) ; and (2) after controlling for college environments and experiences (blocks 3 and 4). It is important to remember that because regression analyses only include students who earned a bachelor's degree in SME, variables entering regression equations serve to distinguish science majors who pursue SME graduate degrees from science majors who do not. This is, of course, quite a different question than asking what predicts enrollment in SME graduate programs among all college students.

Table 4 lists the predictors of women's enrollment in SME graduate programs. Variables entering the regression account for 26.9 percent of the variance in the dependent variable. Among student background characteristics (inputs), the strongest predictor of women's enrollment in SME graduate programs is having a pre-college interest in making a theoretical contribution to science. The importance of an early commitment to science has been reported in other studies on science persistence; the present study demonstrates that even among women who have persisted towards an SME bachelor's degree (an achievement itself symbolizing science commitment), the decision to pursue an SME graduate degree is further influenced by a pre-college commitment to science.

Women's pursuit of SME graduate degrees is also positively affected by having a mother who is either a research scientist or a college teacher. These findings likely represent the importance of having a female role model in the sciences—one who has probably experienced graduate education herself. Having a mother who is a college professor or scientific researcher would not only be a useful source of information and guidance about graduate school, but would also serve to counteract prevailing myths that careers in science are incompatible with motherhood.

Two input variables enter as negative predictors of the decision to enroll in SME graduate programs. First, women with a "social activist" personality type (i.e., women who are more strongly committed to helping others and to effecting social change) are less likely to continue on the path towards becoming a research scientist. This is consistent with the earlier finding that women who are more concerned with the "social good" of their career choice do not persist in science during the undergraduate years (Sax, 1994b). Second, women whose father is a doctor are less likely to pursue a career in research science. Given the results previously reported in Table 3, one may suspect that for women who earn undergraduate SME degrees, having a father who is a doctor probably influences the decision to enroll in medical school instead.

Among freshman year major and career choice variables, two enter as positive predictors of the decision to enroll in SME graduate programs: majoring in the physical sciences and aspiring to be an engineer. These simply indicate that among SME undergraduates, those who enter college with the intent to major in the physical sciences or pursue engineering careers are more likely to pursue SME graduate degrees later on. This again reflects the importance of having an early commitment to SME.

Two college environments enter the regression as predictors of women's SME graduate school enrollment. First is the positive effect of attending a college where peers are more oriented towards science (i.e., peers show a freshman year interest in making scientific contributions through careers in scientific research). This result is consistent with previous findings that a peer environment that encourages and values science positively contributes to women's decision to remain in science (Higher Education Research Institute, 1992). Second, women are more likely to pursue SME graduate education if their undergraduate institution is a private nonsectarian four-year college (i.e., liberal arts colleges). This result is in line with Bielby's (1978) finding that women were more likely to pursue male-dominated fields if they attended liberal arts colleges.

Several student involvement/perception variables enter as predictors of women's graduate science enrollment, accounting for nearly half the total variance accounted for by all variables. The strongest predictor is women's 1989 commitment to making a theoretical contribution to science. The fact that this variable enters the equation after the 1985 pretest on this variable is controlled, and that both remain significant at the final step in the equation, suggests that not only having a commitment to science, but increasing this commitment during college, promotes women's interest in pursuing careers in scientific research. Other positive predictors of women's enrollment in SME graduate programs are college grades, interaction with faculty, time devoted to studying, and self-reported increased interest in attending graduate school. In other words, among women who have earned a bachelor's degree in science, those who are more academically "integrated" are more likely to consider remaining in higher education to pursue an SME graduate degree.

Four 1989 variables negatively predict enrollment in SME graduate programs. First, women are less likely to pursue SME graduate degrees if their career decisions are based on the desire to "make a contribution to society." Similar to the findings reported from the input block, this finding suggests that women who are motivated by a commitment to social change are deterred from SME careers. Women are also less likely to pursue a career in science if they place a high priority on raising a family. This finding is consistent with results reported in studies of undergraduate science persistence (Sax, 1994b; Seymour & Hewitt, 1994). Finally, two negative predictors of SME graduate enrollment relate to women's current financial situation and expected financial rewards: choosing a career because it is "well-paying" and hours per week working for pay during college. While this first finding is not surprising—

that women concerned with making money will be deterred from pursuing SME careers—it is somewhat disheartening to consider that women science students who must work for pay during college will be less likely to pursue SME graduate programs. Given the time demands of SME majors, it is quite likely that women holding a job will have little additional time to devote to such activities as preparing for and applying to graduate school. Such a finding certainly supports the need for more fellowships and scholarships for women in undergraduate science programs.

Table 5 displays the significant predictors of men's enrollment in SME graduate programs. Variables entering this equation account for 26.7 percent of the variance on the dependent variable (nearly identical to the percentage reported for women). The strongest input predictor is the "scholar" typology, suggesting that those male undergraduate science majors who are more academically ambitious and self-confident will be more likely to enroll in SME graduate programs. Other positive input predictors include the desire to make a theoretical contribution to science (although the effect disappears by the final step (see below)), high school GPA, and race: white. This latter variable certainly reflects the increasing underrepresentation of minority students at each level in the science pipeline.

Negative input predictors indicate that men are less likely to pursue SME graduate degrees if they place a high priority on raising a family (similar to the effect for women) and have "status striving" orientations (e.g., aspire towards positions of authority, responsibility, and wealth). This latter finding reinforces the notion that men do not perceive science careers as leading to high status positions or financial success; hence, they are less "attractive" careers for men.

Among freshman year majors and careers, three have positive effects on the ultimate decision to attend SME graduate programs: research scientists career aspirations, and engineering and physical science majors. Aspiring towards a career as a doctor, on the other hand, reduces the likelihood that an undergraduate science major will pursue a master's or Ph.D. program in SME.

Only two environmental measures affect men's decision to enroll in an SME graduate program. First is the positive effect of attending an institution where students have a high level of science preparation. In other words, men who attend institutions where other students have taken many math and science courses in high school will be more likely to remain in science for an SME graduate degree.

Similar to the finding reported for women, this result reflects the positive influence of having a peer group that shows an interest in science.

Second is the positive effect of attending an undergraduate institution with a high proportion of women. This is the most puzzling finding to emerge from this research. It was expected that the percentage of women in the institution would have a positive effect on women's pursuit of SME graduate degrees; instead, we find that men are positively affected by this environment. One explanation relates to the grades earned in college, since it has been shown that men earn higher grades in environments containing greater numbers of women (Sax, 1996). It is possible that gender composition indirectly promotes men's interest in SME graduate programs through its effect on college grades. However, further analysis of the present study shows that this indirect effect accounts for some, but not all, of the effect of gender composition. Clearly, more research is needed to better understand the type of environment that is created when more women are enrolled at an institution.

Ten student involvement/perception variables enter the regression for men, accounting for half of the total variance accounted for by all variables in the equation. Similar to what was found among women are the negative effects of choosing a career because it pays well and the positive effects of undergraduate grades, interaction with faculty, self-reported increased interest in graduate school, and the 1989 commitment to make a theoretical contribution to science. However, contrary to what was found for women, once the 1989 "theoretical contribution" variable entered the equation, the effect of the 1985 pretest on this variable completely disappeared. In other words, the effect of men's pre-college commitment to making a theoretical contribution to science is entirely translated into their 1989 commitment, and does not have any lasting effects.

Among variables entering only for men include the positive effect of feeling "overwhelmed" during college and the negative effect of socializing with friends. While it would be difficult to conclude that stress promotes interest in SME careers and that socialization deters students from science, certainly these findings suggest that the level of commitment required to prepare for SME graduate programs is associated with a greater sense of stress and less time for socializing with friends. Given this, it is perhaps no surprise that those men who choose a career because they believe people in the field would be enjoyable to work with are less likely to choose SME careers.

Finally, a somewhat contradictory set of findings emerge: Men who choose a career because it is interesting are more likely to pursue SME careers, while those who choose a career because they believe the work would be challenging are less likely to pursue SME careers. While the reasons for this are not immediately clear, one possibility is that students equate "challenging" work with "difficult" work, and that those who perceive science careers as more difficult will choose not to pursue SME at the graduate level.

Conclusion

This study set out to explore what student characteristics and undergraduate environments and experiences lead men and women who have earned a bachelor's degree in science, mathematics, or engineering to enroll in an SME graduate program. As expected, there were some important gender differences in the factors predicting this outcome, most notably in the area of students' motivations for their careers. Confirming what previous research on undergraduate SME persistence has shown, men and women have different motivations guiding their choice of a career. For men, the desire to occupy positions of status and authority drives many of them away from SME research careers. For women, it is the desire to influence social change and make a contribution to society that influences the decision not to continue with SME at the graduate level. This tells us that although the improvement of the human condition is a central focus of much of science and engineering research, apparently that message is not being transmitted clearly enough to students.

A number of factors influence both men's and women's decision to pursue SME graduate education. In particular, undergraduate science majors are more likely to continue the study of SME if they have an early (pre-college) commitment to science, a peer environment that values science, and higher levels of academic involvement in college. The fact that these factors have also emerged in previous studies on science persistence at the K-12 and undergraduate levels reinforces their continued importance at every step in the science pipeline. Other influences on both men's and women's career decision is the desire to make money and raise a family. Those who place more importance on these life goals are turned away from science, even if they have persisted in science through the undergraduate level. While it is true that careers in scientific research tend to offer fewer financial rewards than other popular alternatives, such as business and medicine, there is little empirical evidence that science careers (as opposed to other careers) compromise one's ability to raise a family. We must continue to explore the messages that are being transmitted about the life of a scientist and examine the extent to which such stereotypes have basis in reality.

Finally, it is important to remember that this study focuses on a particular form of persistence—towards a research career in science and engineering. As expected, the decision not to pursue SME graduate degrees is not necessarily the decision to abandon science altogether. Among biological science undergraduates who attend graduate/professional school, more than half of men and more than one-third of women chose the field of medicine. Similarly, education is a popular choice of graduate school major, particularly for women from undergraduate math/computer science programs. Given the continuing need for K-12 teachers with strong math/science backgrounds, it would be difficult to argue that SME students pursuing the teaching profession have "abandoned" science. Indeed, one might argue that they will serve to better train the scientists and engineers of tomorrow.

Although the present study was able to provide insight into men's and women's decision to pursue SME at the graduate level, it is faced with some important limitations. First, the size of the sample does not permit an exploration of how the decision to attend graduate school varies across undergraduate SME majors. Clearly, this study provides evidence of such differences, particularly given the number of biological science majors attending medical school. Second, this study does not explore SME persistence beyond the point of graduate school enrollment. It is vital to know the extent to which men and women are able to obtain the graduate degrees to which they have aspired. What obstacles are faced in the pursuit of SME graduate degrees? Do these differ by gender? The next step in this research is to address such questions using the information on graduate school experiences contained in the nine-year follow-up survey.

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Table 1
Distribution of men and women across undergraduate science fields

Field of bachelor's degree	Total	Women	Men
Biological sciences [a]	795	465	330
Engineering [b]	990	218	772
Physical sciences [c]	330	126	204
Mathematical/Computer sciences [d]	448	217	231
Total science majors	2,563	1,026	1,537

[a] Includes general biology, biochemistry/biophysics, botany, marine (life) science, microbiology/bacteriology, zoology, and other biological science.
[b] Includes aeronautical/astronautical, civil, chemical, electrical/electronic, industrial, mechanical, and other engineering.
[c] Includes astronomy, atmospheric science(incl. meteorology), chemistry, earth science, marine science (incl. oceanography), physics, and other physical science.
[d] Includes mathematics, statistics, and computer science.

Table 2
Undergraduate to Graduate Transition (Weighted[a] percentages)

Undergraduate major	Unweighted N	Percent enrolling in SME graduate program	Percent enrolling in other graduate program	Percent not attending graduate school
Biological sciences				
Women	465	17.2	43.1	39.7
Men	330	17.4	44.3	38.2
Engineering				
Women	218	32.2	17.4	50.3
Men	772	32.1	18.5	49.4
Physical sciences				
Women	126	28.0	23.8	48.3
Men	204	32.9	28.3	38.7
Mathematical/ Computer Sciences				
Women	217	12.4	23.8	64.1
Men	231	30.0	16.7	53.2

[a] Responses are weighted to compensate for response bias and sampling bias within the sample of 12,376 respondents. Weighted counts approximate the results we would expect to receive if the nine-year follow-up survey was completed by the 1.5 million students enrolling as first-time, full-time freshman in the fall of 1985.

Table 3
Most Popular Graduate Majors Among SME Undergraduates Attending Graduate School (Weighted [a] percentages)

Undergraduate Major	Graduate Major Selected: Women (%)	Graduate Major Selected: Men (%)
Biological Science	Medicine/Vet. (36.8) Biological Science (25.7) Education (6.2)	Medicine/Vet. (52.0) Biological Science (19.9) Business (4.6) Education (4.5)
Engineering	Engineering (54.2) Business (17.2) Math/Comp. Sci. (10.1) Medical/Vet. (4.9) Law (4.8)	Engineering (57.2) Business (14.9) Medical/Vet (5.0) Law (4.9) Math/Comp. Sci. (4.8)
Physical Sciences	Physical Sciences (28.6) Medical/Vet (18.2) Biological Science (10.9) Engineering (10.8) Business (10.3) Pharmacy (5.5) Math/Comp. Sci. (4.5)	Physical Sciences (48.9) Medical/Vet. (15.6) Education (13.2) Business (7.0) Engineering (5.0)
Math/Computer Sciences	Education (31.3) Math/Comp. Sci. (30.6) Business (24.8)	Math/Comp. Sci. (57.6) Business (20.1) Engineering (6.6) Education (5.0)

[a] Responses are weighted to compensate for response bias and sampling bias within the sample of 12,376 respondents. Weighted counts approximate the results we would expect to receive if the nine-year follow-up survey was completed by the 1.5 million students enrolling as first-time, full-time freshman in the fall of 1985.

Table 4

Significant Predictors of Enrollment in Science, Math, and Engineering Graduate Programs (Women, N = 732)

Variable	Women: Simple correlation	Women: Beta after inputs	Women: Final beta
<u>Input Characteristics</u>			
Positive			
85 Goal: Make theoretical contribution to science	.18	.16 **	.11 **
Mother's career: Research Scientist	.12	.09 *	.06
Mother's career: College Teacher	.08	.08 *	.03
Negative			
Social activist typology	-.08	-.10 **	-.09 **
Father's career: Doctor	-.10	-.06	-.07 *
Rsq		8.0%	
<u>85 Major and Career</u>			
Positive			
85 major choice: Physical Sciences	.18	.16 **	.13 **
85 career aspirations: Engineer	.15	.15 **	.16 **
Rsq		12.1%	
<u>Institution and Peer Environmental Characteristics</u>			
Positive			
Peer science orientation	.17	.11 **	.16 **
Private non-sectarian four-year college	.07	.09 **	.04
Rsq		14.7%	
<u>Student Involvement & Perceptions</u>			
Positive			
89 Goal: Make theoretical contributions to science	.25	.23 **	.19 **
Undergraduate G.P.A.	.15	.14 **	.10 **
Interaction with faculty	.13	.15 **	.11 **
Self-change interest in graduate school	.11	.13 **	.11 **
Hours per week spent studying	.14	.12 **	.09 *
Negative			
Chose career because it pays well	-.13	-.13 **	-.11 **
Choose career to contribute to society	-.05	-.04	-.12 **
89 Goal: Raise a family	-.15	-.12 **	-.11 **
Hours per week spent working for pay	-.08	-.07	-.07 *
Rsq		26.9%	

* $p < .05$, ** $p < .01$

Table 5
Significant Predictors of Enrollment in Science, Math, and Engineering Graduate Programs (Men, N = 1,139)

Variable	Men		
	Simple correlation	Beta after inputs	Final beta
Input Characteristics			
Positive			
Scholar typology	.13	.10 **	.08 *
Race: White/Caucasian	.11	.09 **	.06 *
85 Goal: Make theoretical contribution to science	.09	.07 *	-.01
Father's career: Engineer	.08	.07 *	.05
High school G.P.A.	.12	.07 *	.01
Negative			
Status Striver typology	-.10	-.10 **	-.05
Goal: Raise a family	-.10	-.08 **	-.07 **
Rsq		6.5%	
85 Major and Career			
Positive			
85 career aspirations: Research Scientist	.15	.10 **	.07 *
85 major choice: Engineering	.09	.11 **	.17 **
85 major choice: Physical Science	.13	.08 *	.06 *
Negative			
85 career aspirations: Doctor	-.16	-.10 **	-.11 **
Rsq		10.9%	
Institution and Peer Environmental Characteristics			
Positive			
Peer science preparation	.05	.00	.10 **
% Women enrolled	.07	.13 **	.14 **
Rsq		13.0%	
Student Involvement & Perceptions			
Positive			
89 Goal: make theoretical contributions to science	.24	.26 **	.18 **
Self-change interest in graduate school	.22	.23 **	.17 **
Undergraduate G.P.A.	.26	.23 **	.16 **
Chose career because it is interesting	.06	.06 *	.07 *
Interaction with faculty	.13	.12 **	.06 *
Felt overwhelmed	.04	.06	.06 *
Negative			
Chose career because it pays well	-.15	-.11 **	-.12 **
Chose career because enjoy working with people in field	-.09	-.06 *	-.10 **
Hours per week socializing with friends	-.09	-.09 **	-.08 **
Chose career because it is a challenge	-.02	-.02	-.09 **
Rsq		26.7%	

* p <.05, ** p < .01

Appendix A

Variable Definitions and Coding Scheme

Dependent Variable	
Enrolling in SME graduate major in 1994	Dichotomous: 1="no," 2="yes."
Input Characteristics (Block 1)	
SAT Verbal	Ranges from 200-800.
SAT Math	Ranges from 200-800.
Average High School Grades (self-report)	Eight-point scale: 1="D," to 8="A or A+."
Race: White/Caucasian	Dichotomous: 1="no," 2="yes."
Race: Black/Afro-American	Dichotomous: 1="no," 2="yes."
Race: American Indian	Dichotomous: 1="no," 2="yes."
Race: Mexican-American	Dichotomous: 1="no," 2="yes."
Race: Puerto Rican-American	Dichotomous: 1="no," 2="yes."
Activities in 1985: Used personal computer	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1985: Was bored in class	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1985: Tutored another student	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1985: Participated in science contest	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1985: Felt overwhelmed	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1985: Felt depressed	Three-point scale: 1="not at all," to 3="frequently."
Reason for Attending College: Make more money	Three-point scale: 1="not important," to 3="very important."
Reason for Attending College: Learn more about things	Three-point scale: 1="not important," to 3="very important."
Reason for Attending College: Prepare for Grad/Prof school	Three-point scale: 1="not important," to 3="very important."
Concern about Finances	Three-point scale: 1="no concern," to 3="major concern."

Estimated parental Income	Fourteen-point scale: 1="less than $6000," to 14=$150,000 or more."
Father's education	Eight-point scale: 1="grammar school or less," to 8="graduate degree."
Mother's education	Eight-point scale: 1="grammar school or less," to 8="graduate degree."
Science Preparation	Four-item composite scale total representing total number of years of math, physical science, biological science, and computer science taken in high school.
Life Goal in 1985: Raise a Family	Four-point scale: 1="not important," to 4="essential."
Life Goal in 1985: Make theoretical contribution to science	Four-point scale: 1="not important," to 4="essential."
Father's Career: College Teacher Father's Career: Doctor (MD or DDS) Father's Career: Engineer Father's Career: Research Scientist	All dichotomous: 1="no," 2="yes."
Mother's Career: College Teacher Mother's Career: Doctor (MD or DDS) Mother's Career: Engineer Mother's Career: Research Scientist	All dichotomous: 1="no," 2="yes."
Scholar Typology	Six-item factor scale (see Appendix B).
Activist Typology	Four-item factor scale (see Appendix B).
Artist Typology	Four-item factor scale (see Appendix B).
Hedonist Typology	Four-item factor scale (see Appendix B).
Leader Typology	Three-item factor scale (see Appendix B).
Status Striver Typology	Five-item factor scale (see Appendix B).
Number of typology flags marked "yes"	Dichotomous: 1="no," 2="yes."
Major/Career Choice (Block 2)	
Student's Major: Biological Science Student's Major: Engineering Student's Major: Math, Stat., Comp Sci Student's Major: Physical Sciences	All dichotomous: 1="no," 2="yes."

Student Career: Business	All dichotomous: 1="no," 2="yes."
Student Career: College Teacher	
Student Career: Doctor (MD or DDS)	
Student Career: Teacher (Elementary or Secondary)	
Student Career: Engineer	
Student Career: Lawyer	
Student Career: Research Scientist	
College Environments (Block 3)	
Institutional Characteristics	
Undergraduate FTE enrollment	Total enrollment counts for FTE.
Percentage of women	Percent enrollment of women.
Instructional expenditures	Percent of total expenditures spent on instruction.
Institutional type: Public Univ.	All dichotomous: 1="no," 2="yes."
Institutional type: Public 4-year	
Institutional type: Private Univ.	
Institutional type: Non-Sectarian 4-year	
Institutional type: Catholic 4-year	
Institutional type: Protestant 4-year	
Aggregates for Full-time Undergraduates Science Faculty	
% female science faculty	Gender composition of science faculty.
% Ph.D.s	Ph.D. composition of science faculty.
mean science faculty morale	Fourteen item factor scale (see Appendix B).
mean research orientation	Ten item factor scale (see Appendix B).
mean active learning	Ten item factor scale (see Appendix B).
perception: faculty are student oriented	Seven item factor scale (see Appendix B).
Institutional Peer Mean Factor Scores	
Peer mean intellectual self-esteem	Eight item factor scale (see Appendix B).
Peer mean scientific orientation	Three item factor scale (see Appendix B).
Mean socio-economic status	Average parental income & education of '85 freshmen
Mean high school science preparation biology, mathematics, and physical science.	Average number of high school courses taken in.
College Experiences/Involvements (Block 4)	
Average undergraduate G.P.A.	Six-point scale: 1="C- or less," to 6="A ."
Hrs. spent in classes/labs	Eight-point scale: 1="none," to 8="over 20."
Hrs. spent studying/homework	Eight-point scale: 1="none," to 8="over 20."
Hrs. spent socializing with friends	Eight-point scale: 1="none," to 8="over 20."
Hrs. spent working for pay	Eight-point scale: 1="none," to 8="over 20."
Hrs. spent at religious services/meetings	Eight-point scale: 1="none," to 8="over 20."

Student to Student Contact	Twelve-item factor scale (see Appendix B).
Student to Faculty Contact	Nine-item factor scale (see Appendix B).
Satisfaction w/courses in major field	Five-point scale: 2="dissatisfied," to 5="very satisfied."
Satisfaction w/overall quality of instruction	Five-point scale: 2="dissatisfied," to 5="very satisfied."
Satisfaction w/lab facilities and equipment	Five-point scale: 2="dissatisfied," to 5="very satisfied."
Satisfaction w/career counseling and advising	Five-point scale: 2="dissatisfied," to 5="very satisfied."
Satisfaction w/overall college experience	Five-point scale: 2="dissatisfied," to 5="very satisfied."
Self-rated change in problem solving skills	Five-point scale: 1="much weaker," to 5="much stronger."
Self-rated change in interest in grad/prof school	Five-point scale: 1="much weaker," to 5="much stronger."
Self-rated change in preparation for grad/prof school	Five-point scale: 1="much weaker," to 5="much stronger."
Life Goal in 1989: Raise a family	Four-point scale: 1="not important," to 4="essential."
Life Goal in 1989: Theoretical contribution to science	Four-point scale: 1="not important," to 4="essential."
Activities in 1989: Felt overwhelmed	Three-point scale: 1="not at all," to 3="frequently."
Activities in 1989: Felt depressed	Three-point scale: 1="not at all," to 3="frequently."
Career choice: Job opportunities available	Four-point scale: 1="not important," to 4="essential."
Career choice: Enjoy working w/ people in field	Four-point scale: 1="not important," to 4="essential."
Career choice: Work is interesting	Four-point scale: 1="not important," to 4="essential."
Career choice: Pays well	Four-point scale: 1="not important," to 4="essential."

Career choice: Satisfies parent's hopes	Four-point scale: 1="not important," to 4="essential."
Career choice: Work is challenging	Four-point scale: 1="not important," to 4="essential."
Career choice: Can make contribution to society	Four-point scale: 1="not important," to 4="essential."
Career choice: Oppty for rapid career advancement	Four-point scale: 1="not important," to 4="essential."
Career choice: Oppty for freedom of action	Four-point scale: 1="not important," to 4="essential."

Appendix B

Items Constituting Factor Scales

Scholar Typology

Self-rated academic ability (self-rating)[3]
Self-rated math ability (self-rating)[3]
Intellectual self-confidence (self-rating)[3]
Graduated high school with honors (expectation)[4]
Elected to honor society (expectation)[4]
Highest degree planned (aspiration)[7]

Social Activist Typology

Influence political structure (life goal)[2]
Influence social values (life goal)[2]
Help others in difficulty (life goal)[2]
Participation in community action program (life goal)[2]

Artist Typology

Achieve in a performing art (life goal)[2]
Create artistic works (life goal)[2]
Self-rated artistic ability (self-rating)[3]
Self-rated writing ability (self-rating)[3]

Hedonist Typology

Smoked cigarettes (activity)[5]
Drank beer (activity)[5]
Stayed up all night (activity)[5]
Legalize marijuana (opinion)[8]

Leader Typology

Self-rated leadership ability (self-rating)[3]
Self-rated popularity (self-rating)[3]
Social self-confidence (self-rating)[3]

Status Striver Typology

Become authority in own field (life goal)[2]
Obtain recognition from colleagues (life goal)[2]
Have administrative responsibility (life goal)[2]
Be very well off financially (life goal)[2]
Be successful in own business (life goal)[2]

Student-to-student interaction

- Member of fraternity/sorority (activity)[1]
- In campus protest/demonstration (activity)[1]
- Elected to student office (activity)[1]
- Discuss course content with students (activity)[5]
- Worked on a group project (activity)[5]
- Tutored another student (activity)[5]
- Participated in intramural sports (activity)[5]
- Student clubs/groups (hours per week)[6]
- Little student contact outside class (opinion)[9]
- Students don't socialize regularly (opinion)[9]
- Opportunities for extracurricular activities (satisfaction)[10]
- Campus social life (satisfaction)[10]

Student-to-faculty interaction

- Worked on professor's research (activity)[1]
- Assisted faculty in teaching class (activity)[1]
- Been guest in professor's home (activity)[5]
- Talk with faculty outside class (hours per week)[6]
- Many opptys for fac-student socializing (opinion)[8]
- Easy to see faculty outside office hrs. (opinion)[9]
- Little contact between students & faculty (opinion)[9]
- Opportunity to talk to professors (satisfaction)[10]
- Contact with faculty/administration (satisfaction)[10]

Science Faculty Morale

- Job Satisfaction (satisfaction)[10]
- Autonomy and independence (satisfaction)[10]
- Undergraduate course assignments (satisfaction)[10]
- Opportunity for scholarly pursuits (satisfaction)[10]
- Working conditions (satisfaction)[10]
- Teaching load (satisfaction)[10]
- Relationships with administration (satisfaction)[10]
- Relationships with other faculty (satisfaction)[10]
- Job security (satisfaction)[10]
- Competency of colleagues (satisfaction)[10]
- Graduate course assignments (satisfaction)[10]
- Visibility for jobs at other institutions (satisfaction)[10]
- Salary and fringe benefits (satisfaction)[10]
- Quality of students (satisfaction)[10]

Science Faculty Research Orientation

Articles published in academic journals (number published)
Professional writings published or accepted for publication in the last two years (number published)
Chapters published in edited volumes (number published)
Interests lie primarily in teaching or research - scored for research
Intra- or extramural funds received for research[1]
Importance of engaging in research (life goal)[2]
Importance of becoming an authority in field (life goal)[2]
Importance of obtaining recognition from colleagues for contributions in field (life goal)[2]
Time spent on research and scholarly writing (hours spent per week)[6]
Time away from campus for professional activities (days per year)[11]

Science faculty orientation towards active learning teaching methods

Cooperative learning in small groups (activity)[1]
Student presentations (activity)[1]
Group projects (activity)[1]
Experiential learning or field studies (activity)[1]
Student evaluations of each other's work (activity)[1]
Independent projects (activity)[1]
Student-selected topics for course content (activity)[1]
Class discussions (activity)[1]
Lecture (activity)[1]
Student-developed activities (activity)[1]

Perception: Faculty are student-oriented

Faculty are interested in students' academic problems[12]
Faculty are interested in students personal problems[12]
Faculty are committed to the welfare of the institution[12]
Faculty are sensitive to the issues of minorities[12]
Faculty are easy to see outside of office hours[12]
Students are treated like numbers in a book[12]
Many opportunities for student-faculty interaction[12]

Peer intellectual self-esteem

Academic ability (self-rating)[3]
Public speaking ability (self-rating)[3]
Drive to achieve (self-rating)[3]
Leadership ability (self-rating)[3]
Intellectual self-confidence (self-rating)[3]
Writing ability (self-rating)[3]
Mathematical ability (self-rating)[3]
Election to an academic honor society (expectations)[4]

Peer scientific orientation

Scientific researcher (career choice)[1]
College teacher (career choice)[1]
Make a theoretical contribution to science (life goal)[2]

NOTE: Detailed descriptions of factors are reported in Astin (1993).

1 Dichotomous: 1="no," 2="yes."
2 Four-point scale: 1="not important," to 4="essential."
3 Five-point scale: 1="lowest 10%," to 5="highest 10%."
4 Four-point scale: 1="no chance," to 4="very good chance."
5 Three-point scale: 1="not at all," to "3=frequently."
6 Eight-point scale: 1="none," to 8="over 20."
7 Five-point scale: 1= "no degree," 2="vocational certificate, associate's degree, or other," 3="bachelor's degree or divinity degree (B.D. or M.Div)," 4="master's degree," 5="doctorate degree (Ph.D., Ed.D, M.D., D.O., D.D.S., D.V.M., LL.B, or J.D.)."
8 Four-point scale: 1="disagree strongly," to" 4="agree strongly."
9 Three-point scale: 1="not descriptive," to " 3="very descriptive."
10 Four-point scale: 2="dissatisfied," to" 5="very satisfied."
11 Seven-point scale: 1="none," to 7="50+."
12 Four-point scale: 1="disagree strongly," to 4="agree strongly."

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