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PREDICTING GENDER AND MAJOR-FIELD DIFFERENCES IN MATHEMATICAL SELF-CONCEPT DURING COLLEGE

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Self-ratings of mathematical ability produce some of the largest gender differences among first-year college students. Further, mathematical self-concept is the one measure of academic self-concept that declines during college. However, little research has focused on the predictors of math confidence for college students. This study examines factors related to changes in mathematical self-concept during college and focuses specifically on how these factors differ by gender and major field. Regression results indicate that traditional predictors of math confidence operate differently for men and women in science and nonscience fields.

INTRODUCTION

Among academic self-rating measures, self-concept in math ranks near the bottom among college students: while 53.8% of first-year college students rate themselves "above average" or in the "highest 10%" in academic ability, only 37.7% choose these top categories for mathematical ability (Astin, Korn, Sax, & Mahoney, 1994). During the college years, while students gain confidence in their overall academic abilities, their confidence in math has been shown to decline (Astin, 1977, 1993). Additionally, such declines occur disproportionately among women (Sax, 1994a).

These findings are especially discouraging given the well-documented connection between self-concept and achievement (Astin, 1977, 1993; Bailey, 1971; Byrne, 1984; Hansford and Hattie, 1982). Mathematical self-concept has long been shown to be a positive predictor of persistence in math (Sherman, 1983) and performance on tests of math ability (Astin, 1993; Ethington, 1988; Marsh, Smith, & Barnes, 1985; Meece, Parsons, Kaczala, Goff & Futterman, 1982; Sherman, 1982). Even when one controls for math ability, math self-concept is uniquely predictive of a number of college outcomes, including overall college grades, GRE-Quantitative scores, and postcollege scientific career aspirations (Sax, 1993).

Given the importance of math self-concept for college outcomes, it is important to outline the factors that promote math confidence during college. Unfortunately, little research is available on the factors associated specifically with the development of math

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self-concept, since studies of college students tend to incorporate math self-concept into a composite measure of academic self-concept (combining self-ratings of academic ability, writing ability, and math ability into a single measure). Nevertheless, research on national samples of college students has defined numerous predictors of *academic* self-concept that can aid the study of math self-concept, including high school achievement and socioeconomic status (Astin, 1993; Pascarella, Smart, Ethington and Nettles, 1987), institutional size (Smart and Pascarella, 1986), institutional control (Astin, 1993; Pascarella et al., 1987), interaction with faculty (Astin, 1993; Pascarella, 1985a, 1985b), interaction with students (Astin, 1993; Pascarella et al., 1987), tutoring other students (Astin, 1993), and college grades (Smart and Pascarella, 1986; Pascarella et al., 1987).

In an attempt to distinguish the development of math self-concept from that of academic self-concept, Sax (1994a) examined predictors of mathematical self-concept among a national sample of college men and women. Using the database from the Cooperative Institutional Research Program that is used in the present study, this initial study described a number of precollege characteristics, college environments, and student involvement measures that were related to gains in math confidence during college. Once students' initial confidence in math was controlled, it was found that high school grades, Scholastic Aptitude Test (SAT) scores, exposure to and interest in math and science, and parents' education were predictors of math self-concept development during college. Students' choice of college major was also an important predictor of math self-concept: Students who majored in fields that required the use of math skills (such as math, physical science, and engineering) were more likely to gain confidence in math. Math self-concept was also influenced by aspects of the peer environment (such as the negative effects of competition), by institutional type and control, and by college activities that further reinforced students' comfort with numbers (e.g., the number of math and science courses taken, satisfaction with these courses, and tutoring other students).

In retrospect, a limitation of the Sax (1994a) study was that samples included math/science students together with students from all other majors. Because one's major can have a direct impact on the development of academic self-concept (Astin, 1977; Pascarella and Terenzini, 1991), and because there exists a "clear separation between self-concepts in different academic areas" (Marsh et al., 1985, p. 594), it is important to investigate how the development of mathematical self-concept differs between math-intensive majors and all other majors.

A study of the factors predicting math self-concept must also control for gender. Previous research has described persistent gender differences in math confidence at all levels of education (Astin, 1978; MacCorquodale, 1984; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; Meece et al., 1982). Further, women continue to be less likely to major in fields that rely heavily on the use of math, such as the physical sciences and engineering (Astin et al., 1994). Research should, therefore, pay special attention to which factors are pertinent to the development of math confidence among women. An analysis controlling for gender and major differences is especially important when one considers the finding of Hyde et al. (1990) (through meta-analysis) that gender differences in math self-concept become *smaller* as samples become more selective. With respect to the current study, Hyde's results suggest that the math confidence gap between men and women may be smaller in math/science fields than in other fields, since math/science students are likely to be more "selective" with respect to mathematical ability.

OBJECTIVES

Because the development of confidence in a specific field is likely to be related to the amount of exposure a student has to that field, this study analyzes how the predictors of mathematical self-concept differ between men and women in fields that rely heavily on the use of math (e.g., engineering and physical science) and those in fields that typically require minimal math usage (e.g., English and history). The choice of math self-concept as the dependent measure is made in part because it is the one measure of academic self-concept that declines during the college years (Astin, 1977, 1993; Drew, 1992) and in part because it is the aspect of academic self-concept that produces the greatest gender differences throughout all levels of education (Astin, 1978; Hyde et al., 1990; MacCorquodale, 1984; Meece et al., 1982). This study attempts to shed light on whether the factors predicting math self-concept differ depending on students' exposure to math and, additionally, on whether gender differences in math self-concept very between students in math/science and nonmath/science fields.

Using factors that have been shown to predict academic and mathmatical self-concept, this study moves beyond previous research in three primary ways: (a) by analyzing mathematical self-concept specifically, rather than incorporating it in an overall indicator of academic self-concept; (b) by separating students with high exposure to math from all other students: and (c) by analyzing men and women within these two groups separately. Special attention is paid to those women who have remained in math/science fields, for they comprise the small minority of women college students who have chosen math-intensive fields, despite persistent stereotypes of women as less able in math (Meece et al., 1982).

METHOD

Sample

The data in this study are drawn from the Cooperative Institutional Research Program [CIRP] 1985 Freshman Survey and 1989 Follow-Up Survey conducted by the Higher Education Research Institute [HERI] at the University of California, Los Angeles. These data are merged with aggregated data from the 1989–1990 HERI Faculty Survey and enrollment data collected by U.S. Department of Education for the Integated Postsecondary Education Data System [IPEDS]. The sample includes approximately 14,000 students attending 191 coeducational four-year colleges and universities. The specific subgoups used in analyses include 1,322 men and 587 women in math/science majors, and 4,856 men and 7,656 women in all other majors. Math/science majors are drawn from fields with typically high levels of math exposure during college: engineering, physical science, and computer science. Biological science majors are not included in the math/science category because of the significantly fewer college math courses taken by these students (HERI, 1992). Finally, because response rates varied by institution. it was important to avoid biasing the results toward the responses of students from any particular institution. Therefore, a "maximum contribution" limit was imposed on institutions so as to prevent any single institution from contributing more than 1% to the final sample. [See (HERI, 1991) for a complete description of sampling and weighting procedures.]

Research Methods

This study employs the "Input-Environment-Outcome" (I-E-O) methodological framework, which examines the impact of various college environments and experiences on specific student outcomes, after controlling for students' precollege characteristics and experiences (Astin, 1991). Implementation of this model requires that any biasing effects of "input" characteristics, such as students' SAT-math scores, be controlled in order to obtain a relatively unbiased measure of the effect of college environments and college experiences on specific outcomes.

First, for each of the four groups, means and cross tabulations reported levels of mathematical self-concept at the point of college entry, as well as four years later. Second, math self-ratings were compared to students' actual SAT-math scores in order to assess the relative accuracy of math self-concept across the four goups. Finally, forced blocked regession analyses were performed separately for each goup in order to compare how a standard set of self-concept predictors behaves within each subsample. Specifically, each set of predictor variables was forced into the four regressions in the following order: (a) input characteristics, (b) college environments, and (c) college experiences. All analyses were conducted using SPSS-X Release 4.1.

Variables

The dependent variable is students' self-rating of their mathematical ability four years after college entry. Respondents were asked to rate their own mathematical ability as compared with "the average person your age" on a 5-point scale: "highest 10%," "above average," "average," below average," and "lowest 10%." Regression analyses were performed on each of the four subgroups (men and women in math/science and nonmath/science majors) in accordance with the I-E-O model, with three blocks of independent variables added to the regession equation in the temporal sequence in which they may have had an effect on students' math self-concept: (a) 9 input characteristics (including a pretest of math self-concept), (b) 12 measures of the college environment, and (c) 9 measures of student experiences in college. (See Appendixes A and C for a complete list of variables, coding schemes, means, and standard deviations.)

Input characteristics include attributes of the student at the point of college entry that are likely to influence the development of math self-concept during college. Variables in this block include initial math self-rating, SAT scores, high school grades, academic self-concept, mother's and father's education, as well as scientific interest and preparation.

The second block of variables includes measures of the college environment, such as structural characteristics of institutions (selectivity, size, type, and control), as well as characteristics of the peer and faculty environments that might mediate the development of math self-concept during college. Aspects of the peer group are computed separately by institution and include: percent women undergraduates, peer intellectual self-esteem, peer science preparation, and average math and science course taking among students at the institution.

Within the second block, three measures are derived from faculty data. Faculty responses to specific items were aggregated by institution and merged into the student-level data file as measures of the students' college environment. One faculty measure actually represents a dimension of the peer group: the extent to which faculty perceive competition among students at each college. The two remaining faculty measures (computed separately for each institution) are the percent of women faculty and the amount of time faculty spend teaching and advising.

The last block of variables includes measures of student involvement and student experiences in college that have been associated with academic or math self-concept, such as the number of math/science courses taken in college and college grades. This block also includes measures of out-of-classroom activities, such as tutoring or being tutored. Effects associated with any of the nine variables included in this block must be interpreted cautiously, primarily because students report these experiences at the same time that they report their final math self-concept (on the follow-up questionnaire). Because we cannot be sure that a change in math confidence does not *precede* engaging in any of these activities, we cannot assume that such activities are the *cause* of any change in the outcome. Nevertheless, the inclusion of activities and involvement measures will add to our understanding of how the college experience is associated with changes in math self-concept.

RESULTS

For each of the four groups of students, Table 1 describes the mathematical self-concept of students as they enter college (1985) as well as four years later (1989). The most noticeable differences in math self-concept are between students who major in math and science and those who do not. Upon college entry, 52.0% of men and 41.2% of women in math/science majors rate themselves in the "highest 10%" in math ability, as compared with 16.9% of men and 8.6% of women in other majors. Additionally, while men exhibit greater mathematical confidence than women in both major groupings, the gender gap is larger among nonmath/science students.

Table 1 Four-Year Changes in Mathematical Self-Rating

	Math/science majors				All other majors			
	1985		1989		1985		1989	
Self-rating	M	W	M	W	M	W	M	W
Highest 10%	52.0	41.2	49.3	43.8	16.9	8.6	12.9	6.2
Above average	39.0	46.2	41.6	44.5	37.2	34.5	36.6	31.5
Average	8.0	11.6	7.7	10.7	32.1	37.6	34.1	40.1
Below average	1.0	1.0	1.4	1.0	11.9	15.6	14.3	19.0
Lowest 10%	0.0	0.0	0.0	0.0	2.0	3.7	2.0	3.2
Mean	4.42	4.28	4.40	4.31	3.57	3.31	3.47	3.21
(S.D.)	(.68)	(.70)	(.68)	(.69)	(.96)	(.95)	(.94)	(.91)
Four-year mean change			−.02	+.03			−.10	−.10

Note. Chi-square tests indicate statistically significant gender differences and major differences ($p<.001$) in all cases except for gender differences among math/science majors in 1989. Math/science majors: 1.322 men, 587 women. All other majors: 4,856 men, 7,656 women. Math self-concept is scored on a five-point scale: 1 = "Lowest" 10% to 5 = "Highest 10%."

Changes in math self-concept over four years reveal a general decline in math confidence among students in nonmath/science fields (an average decline of −.10). Among students majoring in math/science fields, men experience a slight average decline in math confidence (−.02), while women in these fields become slightly more confident in math (+.03). While such changes are not substantial, note that, on average, the overall *decline* in math self-concept during the college years is *not* shared by women who persist in generally male-dominated math/science fields. In fact, among math/science students, gender differences in math self-concept (significant at $p<.001$ in 1985) essentially disappear during college.

The trends described above indicate a high confidence in math among men and women who major in math and science and an average to above-average math confidence among students in other majors. An important issue is to what extent students' perceived math ability (self-concept) relates to their demonstrated math aptitude. In other words, are students underestimating or overestimating their math skills? One way to examine this is to compare students' math self-concept in 1985 with their scores on the mathematical portion of the SAT (SAT-M). Among the nearly 15,000 students for whom SAT scores and survey data were available, 10% scored at least 670 out of 800 on the SAT-M. Among all students in this sample, 18.7% of men and 6.3% of women scored among this top 10%. In the present study, "underestimation" is defined as scoring in the top 10% on the SAT-M but not rating oneself in the top 10% in math ability. Conversely, "overestimation" is defined as rating oneself in the top 10% in math ability but not scoring in the top 10% on the SAT-M. By comparing students' math confidence with their math ability, we are able to examine the validity of students' math self-concept ratings.

As Table 2 indicates, underestimation of math abilities is least likely among men in math/science and is most likely among women in all other majors. Underestimation among students in nonmath/science majors is striking: among those who scored in the top 10% on the SAT-M, 57.1 % of women. and 46.8 % of men do *not* consider themselves in the highest 10% in math ability. This finding is even more startling when one considers that these students had fairly recently received SAT score reports that included a percentile ranking of their math score among all test takers. While lower rates of underestimation occur among math/science students (22.0% among men, 32.4% among women), these rates nevertheless

Table 2. Comparing Math Self-Concepts with SAT-Math Scores

	Math/science majors		All other majors	
	Men	Women	Men	Women
Underestimators				
Percent of those scoring in top 10% on SAT-Math who do not rate themselves in top 10%	22.0 (491)	32.4 (139)	46.8 (675)	57.1 (385)
Overestimators				
Percent of those *not* scoring in top 10% on SAT-math who rate themselves in top 10%	36.5 (832)	33.0 (448)	11.0 (4.181)	6.8 (7.271)

Note. Numbers in parentheses are samples on which percentages are based.

reflect some hesitation among highly able math/science students to place themselves in the highest category of math ability.

With respect to overestimation, the lowest rates occur among nonmath/science students; only 11% of men and 6.8% of women rate their math abilities higher than their test scores would indicate. However, among math/science students, these rates are much higher (36.5% among men and 33.0% among women). These findings suggest that approximately one third of math/science students believe they have very high mathematical capabilities, even when they did not perform at the highest levels on the SAT-M.

In sum, underestimation of math ability is more likely among nonmath/science students, while overestimation is more likely among math/science students. To some extent, this suggests that the choice of major reflects students' beliefs about their math skills: those who are willing to admit their math ability or to inflate their math confidence are more likely to pursue mathematically demanding fields in college. Finally, note that regardless of whether women major in a math/science field, they are much more likely than men to underestimate their math abilities.

REGRESSION RESULTS

Before the results of regression analyses are discussed, it is important to point out the difficulty of comparing the four regression equations. Mainly, there is a substantial disparity between the size of the subgroups—the largest being women in nonmath/science fields (n = 6,932) and the smallest being women in math/science fields (n = 561). The problem here is that the large samples (nonmath/science students) are more likely to produce "statistically significant" results, even when corresponding regression coefficients are relatively small. On the other hand, smaller samples (math/science students) may have moderately sized regression coefficients that are not considered "significant" but may nevertheless reveal important information about these students.

The challenge is to simultaneously avoid making Type I and Type II errors. Setting a more stringent alpha level is commonly used to avoid making Type I errors (rejecting the null hypothesis when it is actually true). This is especially important when samples are large and the probability of finding statistically significant (but practically meaningless) results becomes greater. On the other hand, when samples are relatively small, we have a greater opportunity for Type II errors (accepting the null hypothesis when it is actually false). As noted in Moore and McCabe (1989), "The use of a significance test with low power makes it unlikely that you will find a significant effect even if the truth is far from the null hypothesis" (p. 492). In other words, one cannot assume that a "nonsignificant" coefficient in the smaller sample indicates no effect. While the "smaller" samples in this study are still somewhat large (561 and 1,288), the point is that in determining significance or importance, it is important to take into consideration the difference between these samples and the comparison goups of 4,390 and 6,932. For this reason, discussion of regression results is limited primarily to those results that do not appear to be "chance" findings and will not be concerned with comparing the statistical significance of findings across equations.

Table 3 provides the results of regression analyses for all four groups. Although variables were entered in three separate blocks, standardized and unstandardized regression coefficients are based on equations after *all* variables have been controlled. The four final

Table 3. Regression Results: Predictors of Math Self-Concept

	Math/science majors				All other majors			
	Men (1,288)		Women (561)		Men (4,390)		Women (6,932)	
Input characteristics								
1985 math self-rating	.37	(.36)***	.38	(.39)***	.50	(.51)***	.52	(.53)***
SAT-Math	.00	(.19)***	.00	(.03)	.00	(.21)***	.00	(.19)***
SAT-Verbal	.00	(-.06)*	.00	(-.10)	.00	(-.09)***	.00	(-.13)***
High school GPA	-.02	(-.04)	-.03	(-.05)	-.02	(-.04)**	.00	(.00)
1985 academic self-rating	.09	(.08)**	.06	(.06)	.06	(.04)**	.03	(.02)
Father's education	.01	(.04)	.01	(.03)	.00	(.00)	-.01	(-.03)**
Mother's education	-.03	(-.07)*	-.03	(-.09)	-.01	(-.02)	.00	(.00)
Years of math/science in high school	-.01	(-.04)	.00	(.00)	.01	(.01)	.01	(.02)*
Scientific orientation	.01	(.01)	-.02	(-.02)	-.01	(-.01)	-.01	(-.01)
R^2	.316		.231		.464		.451	
College environments								
Selectivity	.01	(.10)	.01	(.13)	.00	(-.03)	.00	(-.03)
Public university	-.11	(-.07)	-.08	(-.04)	-.16	(-.07)**	-.04	(-.02)
Private university	.06	(.04)	-.05	(-.03)	.00	(.00)	.05	(.02)
Private four-year	-.04	(-.03)	-.02	(-.02)	.00	(.00)	.01	(.00)
Undergraduate enrollment	.00	(.03)	.00	(.02)	.00	(.0 1)	.00	(.00)
% Female faculty	.00	(.05)	.00	(.01)	.00	(-.02)	.00	(-.01)
% Female undergraduates	-.01	(-.11)*	.00	(.01)	.00	(.02)	.00	(.02)
Peers: # Math/science courses in college	-.01	(-.04)	-.02	(-.07)	-.02	(-.04)*	-.02	(-.04)**
Peers: Intellectual self-esteem	-.04	(-.09)	-.03	(-.07)	.01	(.02)	.01	(.02)
Peers: Science preparation in high school	-.07	(-.08)	-.03	(-.03)	.00	(.00)	.01	(.01)
Faculty: Hours teaching and advising	-.05	(-.07)	-.06	(-.08)	-.06	(-.06)	-.03	(-.03)
Faculty perception: Student competition	-.01	(-.01)	.06	(.03)	-.11	(-.04)*	-.10	(-.04)*
R^2	.328		.244		.468		.454	
College experiences								
Satisfaction: Science and math courses	.07	(.09)***	.12	(.14)***	.11	(.10)***	.11	(.10)***
Academic interaction with classmates	.01	(.01)	.01	(.01)	.00	(.00)	.02	(.02)**
Received tutoring in courses	-.06	(-.04)	-.02	(-.01)	-.05	(-.02)*	-.03	(-.02)
Tutored another student	.06	(.06)*	.14	(.14)***	.07	(.05)***	.07	(.05)***
# Math/science courses in college	.02	(.12)***	.02	(.13)**	.03	(.16)***	.03	(.14)***
College grades	.05	(.07)*	.08	(.11)*	.04	(.04)***	.00	(.01)
Worked on independent research project	.01	(.01)	.05	(.06)	.00	(.00)	-.01	(-.01)
Felt overwhelmed	-.01	(-.01)	.02	(.01)	-.03	(-.02)	-.06	(-.04)***
Interacting with faculty	.00	(-.01)	-.04	(-.08)	-.03	(-.05)***	-.03	(-.04)***
Constant	3.71		3.15		1.69		1.12	
R^2	.365		.314		.511		.490	
F	22.60***		7.57***		142.40***		207.48***	

Note: Table displays unstandardized regression coefficients (for comparison across groups), with standardized coefficients in parentheses (for comparison within groups).

* $p<.05$, ** $p<.01$, *** $p<.001$.

regression equations can be computed from the unstandardized regression coefficients and the constants listed in Table 3. The inclusion of all variables accounts for between 31 and 51% of the variance in math self-concept across the four groups.

Input characteristics. Variables included in the input block account for a high proportion of the variance in 1989 math self-concept among nonmath/science men (46.4%) followed by 45.1% for nonmath/science women, 31.6% for math/science men, and 23.1% for women in math/science fields. For all four groups, the strongest predictor of 1989 math self-concept is 1985 math self-concept. While this result is not surprising, it does suggest that regardless of what students experience during the college years, they are unlikely to substantially change their confidence in math.

For three of the four groups, the next strongest predictor of math confidence is students' score on the SAT-Math. Regardless of their initial confidence with math, students with higher scores on the SAT-Math report higher levels of math confidence after four years of college. *The one interesting exception is women in math and science, whose levels of 1989 math confidence appear to be independent of their SAT-Math scores.* Perhaps women who major in mathematically demanding fields do not consider their scores on standardized tests as representative of their actual abilities.

While SAT-Math positively predicts math confidence among most students in the sample, SAT-Verbal scores generally predict lower 1989 math self-ratings. This does not imply that students with higher SAT-Verbal scores will have lower confidence in math (this is clearly not the case, as simple correlations between SAT-Verbal and 1989 math self-concept are positive). However, when key inputs are held constant, namely, 1985 math self-concept and SAT-Math, students who score higher on the SAT-Verbal will tend to have lower math confidence than one would expect, given their generally higher SAT-Math scores ($r_{SAT\text{-}M \times SAT\text{-}V}$ is at least .65 for all four groups). In other words, since students with high SAT-Verbal scores tend to have high SAT-Math scores, we would expect students with high Verbal scores to have higher levels of math confidence. However, once the positive relationship between Verbal and Math scores is controlled, SAT-Verbal is negatively related to math confidence. This finding reflects Marsh's (1986) finding that students consider their math abilities in *relation* to their verbal abilities, such that students with higher verbal skills would tend to underrate their math ability.

Whereas previous research has shown high school achievement to predict academic self-concept (Astin, 1993; Pascarella et al., 1987), results here indicate that when relevant inputs are controlled, high school grades have little or no impact on students' math confidence. What this means is that the relationship between high school grades and 1989 math self-concept is accounted for when initial math self-concept and test scores are controlled. For nonmath/science men, the relationship between high school GPA and 1989 math self-concept actually becomes slightly negative, suggesting that for men who do not pursue mathematically oriented fields in college, those who receive higher grades in high school will tend to become less confident in math during college.

Academic self-confidence in 1985 is positively related to the development of math self-concept for all four groups, but the effects are significant only for men. While such gender differences may not be substantial, they do suggest that men may be more likely than women to include math skills in their conception of academic ability, thus producing a stronger connection between perceptions of academic and mathematical abilities.

Findings for parental education indicate that father's education has a slight negative effect on the math confidence of women in nonmath/science majors and that mother's education has a negative effect on the math confidence of men in math/science fields. Note that while parental education is positively correlated with students' math confidence, results here represent the impact of parents' education when relevant inputs are controlled. In other words, students with highly educated parents may have high levels of math confidence but lower than one would *expect* given their relatively higher levels of ability and self-concept. Such a finding is consistent with the results reported in Sax (1994a), which show negative cross-gender effects of parental education on overall samples of college men and women. The current study helps to delineate *which* men and women experience declines in math confidence owing to the educational level of a parent.

Surprisingly, the remaining two variables in the input block, math/science preparation in high school and scientific orientation, appear to be essentially unrelated to the development of math confidence during college. However, further inspection of regression results reveals that such variables are positively related to the development of math confidence until variables in the college experiences block are controlled (namely, the number of math/science courses taken in college). It could be said, therefore, that high school science preparation and an interest in science contribute to higher confidence in math, but their effects are mediated through geater exposure to math and science during college.

College environments. The inclusion of college environmental variables contributes surprisingly little to the equation for each group. Environmental variables included in these analyses account for less than 2% of the variance in math self-concept within each group. Much of this is explained by the fact that input variables (which are highly correlated with some environmental variables) have already been controlled at this point in the analysis and thus have "washed out" some of the effect of the environment. As an example, the simple correlation between SAT-Math and competitive environments is at least .42 within each of the four groups (indicating that students with higher math scores will tend to enroll in more competitive schools). Therefore, any relationship between peer competitiveness and math self-concept may be reduced once we control for the higher SAT-Math scores of students in competitive environments.

Nevertheless, a few interesting results surface in the environment block. While institutional selectivity produces no significant effects on the nonmath/science samples, selectivity does appear to be associated with gains in math confidence for math/science students (results significant under a relatively liberal significance test, $p<.10$). Such a finding suggests that those students who major in math and science fields in selective institutions gain more confidence in math than math/science students will at less selective colleges.

With respect to institutional type, attending a public university is related to declines in math confidence for men in nonmath/science fields. Such a finding is consistent with Astin (1993) and Pascarella et al. (1987), who report declines in intellectual self-esteem among students attending public institutions. However, it is interesting that in this study, such negative effects are found only among men. Further, while the negative effects of public institutions have traditionally been attributed to their large size, the effects found in this study occur when enrollment is held constant. Perhaps the diversity of curricular and co-curricular opportunities at public universities leads students who do not pursue math/science to develop confidence in new areas, and therefore they view their math abilities as relatively lower than when they entered college.

Another rather peculiar finding is that the percent of women in an institution is related to significant declines in math confidence among men in math/science fields. This finding is likely an artifact of this sample, which includes a number of technical colleges and military schools (schools that emphasize math skills and have very few women). In fact, in a study that excludes single-sex institutions, Sax (1994b) found the proportion of women in the institution to have no effect on men's math confidence.

Finally, for nonmath/science men and women, two environmental variables are associated with slight declines in math confidence: the amount of college math and science taken by peers and the level of competitiveness within the student body. Under a "relative deprivation" framework, such findings make sense—that individuals will feel relatively less confident in math when large numbers of fellow students are pursuing a math and science curriculum or when they feel they are in competition with other students (many of whom have greater mathematical preparation).

College experiences. Variables included in the college experience block account for an additional 7.0% of the variance in math self-concept among women in math/science, 3.7% among men in math/science, 4.3% among men in all other majors, and 3.6% among women in other majors. While the variables that relate to math confidence are relatively similar across regressions, the effects tend to be stronger for women in math-intensive majors.

Among all four groups, gains in math confidence are associated with the number of math and science courses taken and the level of satisfaction with math and science courses. These findings are not surprising, for greater exposure to and satisfaction with college math and science would be likely to enhance confidence with math. However, because we cannot assume a causal relationship between college experiences and math self-concept (both are measured on the follow-up questionnaire), this finding may simply represent the fact that those students who are more confident with their math abilities will be more likely to enroll in and be satisfied with math and science courses.

A more interesting finding is the positive relationship between tutoring other students and the development of math self-concept within all four groups. While such a relationship may be due to a greater likelihood of tutoring among mathematically confident students, this finding nevertheless supports the notion that peer tutoring can result in cognitive benefits for the tutor (Bargh and Schul, 1980). Interestingly, the positive effects of tutoring are strongest among women in math/science majors.

College grades are a significant predictor of math self-concept for all groups except women in nonmath/science fields. The unique contribution of grades to the development of self-concept is not surprising, and it merely confirms similar findings in previous research (Smart and Pascarella, 1986; Pascarella et al., 1987). However, while one would expect a stronger connection between grades and math confidence among students in math-intensive majors than among those in other majors, the fact that such a connection exists among men who pursue other fields, but not women, raises the question of whether men and women differentially interpret the significance of their course performance.

Feeling overwhelmed during college is associated with declines in math self-concept only for women in nonmath/science fields. A similar finding was reported in Sax (1994a) for an overall sample of women; however, separating students by major, we learn that the negative effects of feeling overwhelmed are apparently not shared by those women who major in math/science fields.

Finally, interacting with faculty is associated with significant, although modest, declines in math confidence among students in nonmath/science majors. Negative effects of interacting with faculty are also found among women in math/science fields (significant at $p<.10$). Such findings are at odds with research, which concludes that student-faculty interaction produces gains in academic self-concept (Astin, 1993; Pascarella, 1985a, 1985b).

Why should activities such as working on a professor's research project or talking with faculty outside class enhance students' overall academic self-concept but reduce many students' math self-concept? Such a question should be addressed by research that examines the dynamics of student-faculty interaction among men and women across disciplines.

DISCUSSION

Because mathematical concepts permeate most academic fields, it is important to study what factors contribute to the development of mathematical confidence among college students. Yet, enhancing math confidence among initially confident students is a different challenge than instilling math confidence among students who begin college with lower levels of math self-concept, generally avoid math during college, and experience greater overall declines in math confidence during college. Similarly, given the freshman-year gap in math confidence between males and females, an understanding of the development of math self-concept must attend to differences between men and women. This paper addresses these issues by comparing predictors of math self-concept across four unique subgroups of students (men and women in math/science vs. those in all other fields).

As one might expect, students who major in math and science begin college with high levels of math confidence and generally maintain this confidence during college. Students in other fields, on the other hand, feel only moderately confident in their math abilities and become less confident in their math skills over time. While such findings are not surprising, it is somewhat disturbing that the majority of college students would feel that their math skills have declined relative to their peers.

A more encouraging finding is that, as a group, women who major in math-intensive fields actually gain confidence in math during college. In fact, while the gender gap in math self-concept persists through college for the majority of students, gender differences among math/science students nearly disappear over these four years. What this suggests is that those women who are "put to the test" and major in math and science fields will learn to accept (and admit) their high abilities.

Regression results also reveal unique findings for women who major in math-intensive fields. First, they are the only group for which SAT-Math does *not* have a strong effect on math confidence four years after college entry. Second, feeling overwhelmed by school work does not lower these women's confidence with math, as it does for women in other fields. Third, the benefits of tutoring other students are especially strong for women in math and science. Together. these findings suggest that women who major in math and science fields have an especially strong belief in their abilities—a belief that is not affected by scores on a test four years earlier, that is not diminished by the pressures of their field, and that is reinforced through the strengthening of abilities that comes from teaching others.

The one particularly disturbing finding for women in math and science is that interacting with faculty is associated with declines in math confidence. While such a relationship holds among nonmath/science students, it does *not* hold among men in math and science, suggesting an important difference between the experiences of men and women in the sciences. Given reports of nonfemale-friendly teaching practices in the sciences (e.g., encouraging competitition, relying heavily on a lecture format) (Rosser, 1990, 1993), it may be that the manner in which science faculty *interact* with women is equally nonfriendly. Clearly, research should investigate further the nature of the interaction between science faculty and male and female students, as well as how students perceive this interaction.

One particularly interesting finding for both men and women in math/science fields is the positive effect of institutional selectivity on math self-concept. While the effects of selectivity on self-concept and achievement are well studied, results have often been contradictory, leaving researchers unsure about whether it is better to be a "big fish in a small pond" or a "small fish in a big pond." In other words, when surrounded by a high-ability peer group, will students feel relatively *more* confident (Bassis, 1977) or *less* confident (Davis, 1966) in their mathematical abilities? The fact that attendance at a selective college tends to promote mathematical confidence among math/science students suggests that these students may benefit from their status as "big fish in a big pond."

Finally, college experiences promoting math confidence for all students, regardless of gender or major, include greater exposure to and satisfaction with math and science courses. While these findings are not surprising, they do suggest that even students who major in fields that generally require little or no math can gain mathematical confidence through positive experiences with math. This does not mean that nonmath/science fields should embrace a math-intensive curriculum; rather, these fields could incorporate more mathematical concepts into coursework, so that all students can understand the usefulness of quantitative skills in their specific field of study.

The overall importance of this study is that it takes into consideration the multidimensional nature of self-concept. Instead of using a general self-concept indicator or even an academic self-concept measure, this study is based on a specific subcategory of self-concept—mathematical self-concept. Further, by studying the predictors of math self-concept among men and women in math-intensive majors separately from men and women in all other majors, this study shows how factors traditionally related to math self-concept relate differently to unique subgroups of students. While the majority of factors promoting math self-concept have relatively similar effects across all four groups, the fact that a few important differences emerge suggests that future research on self-concept will benefit from attention to potential differences based on major, gender, or other defining characteristics.

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APPENDIX A

Table A=1. Variable Definitions and Coding Scheme

Dependent variable	
1989 mathematical self-rating	Five-point scale: 1 = "lowest 10%," to 5 = "highest 10%"
Input characteristics	
1985 mathematical self-rating	Five-point scale: 1 = "lowest 10%," to 5 = "highest 10%"
SAT Math	Ranges from 200 to 800
SAT Verbal	Ranges from 200 to 800
1985 academic ability self-rating	Five-point scale: 1 = "lowest 10%," to 5 = "highest 10%"
Average high school grades (self-report)	Eight-point scale: 1 = "D," to 8 = "A or A+"
Mother's education	Eight-point scale: 1 = "grammar school or less," to 8 = "graduate degree"
Father's education	Eight-point scale: 1 = "grammar school or less," to 8 = "graduate degree"
Years of high school math/science	Four-item scale total representing total number of years of math, physical science, biological science, and computer science taken in high school
Scientific orientation	Three-item factor scale (see Appendix B for items)
College environments	
Selectivity	Average SAT (or ACT equivalent) of entering freshmen divided by 10
Public university	All dichotomous: 1 = "no," 2 = "yes"
Private university	(Public four-year category excluded from equations)
Private four-year college	
Size	Undergraduate FTE
Percent women faculty	Percent women among full-fime faculty
Percent women students	Percent enrollment of women
Peer science preparation	Peer mean: number of math/science courses taken in high school
Peer intellectual self-esteem	Eight-item factor scale (see Appendix B for items)
Peer math/science	Peer mean: number of math/science courses taken in college
Faculty teaching and advising	Average number of hours per week faculty spend teaching and advising (faculty self-reports)
Faculty perception: competition among students	Mean faculty belief that "a keen competition among most of the students for high grades" is descriptive of the college: 1 = "not descriptive," 2 = "somewhat descriptive," 3 = "very descriptive"
College experiences	
Number math/science courses	Number of math/science courses taken in college
Satisfaction with math/science courses	Four-point scale: 2 = "dissatisfied," to 5 = "very satisfied"
Average undergraduate grades (self-report)	Six-point scale: 1 = "C- or less," to 6 = "A"
Interaction with faculty	Four-item factor scale (see Appendix B for items)
Academic interaction with classmates	Sum of two dichotomous variables: Discussed course content with students + Worked on a group project for a class
Worked on independent research project	Three-point scale: 1 = "not at all," to 3 = "frequently"
Received tutoring in courses	Three-point scale: 1 = "not at all," to 3 = "frequently"
Tutored another student	Three-point scale: 1 = "not at all," to 3 = "frequently"
Felt overwhelmed	Three-point scale: 1 = "not at all," to 3 = "frequently"

APPENDIX B

Table B=1. Items Constituting Factor Scales

Scientific orientation	
Scientific researcher (career choice)[a]	
College teacher (career choice)[a]	
Make a theoretical contribution to science (life goal)[b]	
Peer intellectual self-esteem	
Academic ability (self-rating)[c]	
Mathematical ability (self-rating)[c]	
Public speaking ability (self-rating)[c]	
Drive to achieve (self-rating)[c]	
Leadership ability (self-rating)[c]	
Intellectual self-confidence (self-rating)[c]	
Writing ability (self-rating)[c]	
Be elected to an academic honor society (expectation)[d]	
Student-faculty interaction	
Been guest in a professor's home (activity)[e]	
Worked on professor's research project (activity)[e]	
Assisted faculty in teaching a class (activity)[e]	
Talked with faculty outside class (hours per week)[f]	

Note. Factors are derived from factor analyses of the responses of 192,453 freshmen to the 1985 CIRP Freshman Survey and 51,574 faculty from the 1989–1990 HERI Faculty Survey. Detailed descriptions of factors are reported in Astin (1993).

[a] Dichotomous: 1 = "no," 2—"yes."
[b] Four-point scale: 1 = "not important," to 4 = "essential."
[c] Five-point scale: 1 = "lowest 10%," to 5 = "highest 10%."
[d] Four-point scale: 1 = "no chance," to 4 = "very good chance."
[e] Three-point scale: 1 = "not at all," to "3 = frequently."
[f] Eight-point scale: 1 = "none," to 8 = "over 20."

APPENDIX C

Table C-1. Means and Standard Deviations

	Math/science majors				All other majors			
	Men (1,288)		Women (561)		Men (4,390)		Women (6,932)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Dependent Variable								
1989 math self-rating	4.40	(.68)	4.31	(.69)	3.47	(.94)	3.21	(.91)
Input characteristics								
1985 math self-rating	4.24	(.68)	4.28	(.70)	3.57	(.96)	3.31	(.95)
SAT-Math	629.14	(88.44)	590.97	(99.76)	557.14	(99.90)	508.89	(96.53)
SAT-Verbal	533.71	(89.39)	520.31	(97.77)	500.10	(94.95)	480.53	(93.71)
High school GPA	6.68	(1.36)	7.07	(1.14)	5.78	(1.56)	6.15	(1.41)
1985 academic self-rating	4.47	(.63)	4.40	(.62)	4.04	(.79)	3.95	(.69)
Father's education	5.76	(2.04)	5.60	(2.05)	5.54	(2.09)	5.33	(2.09)
Mother's education	5.04	(1.82)	5.03	(1.86)	4.96	(1.85)	4.79	(1.82)
Years of math/science in high school	16.53	(1.98)	16.04	(1.81)	15.46	(2.06)	14.80	(2.05)
Scientific orientation	4.36	(.97)	4.13	(1.03)	3.75	(.86)	3.54	(.77)
College environments								
Selectivity	110.60	(12.29)	108.78	(14.70)	105.84	(12.82)	104.03	(12.50)
Public university	1.25	(.44)	1.17	(.37)	1.18	(.38)	1.18	(.39)
Private university	1.30	(.46)	1.28	(.45)	1.22	(.41)	1.19	(.40)
Private four-year college	1.28	(.46)	1.41	(.49)	1.44	(.50)	1.43	(.50)
Undergraduate enrollment	7133.29	(6514.33)	5661.74	(6311.40)	5800.91	(6230.02)	5785.77	(6092.63)
% Female faculty	22.97	(8.06)	25.47	(8.77)	26.51	(8.02)	28.21	(8.22)
% Female undergraduates	41.54	(13.28)	46.86	(11.04)	47.24	(12.31)	51.52	(7.80)
Peers: # Math/science courses in college	11.07	(2.72)	10.14	(2.49)	9.15	(2.03)	8.80	(1.73)
Peers: Intellectual self-esteem	25.68	(1.75)	25.41	(1.63)	24.95	(1.55)	24.64	(1.41)
Peers: Science preparation in high school	15.56	(.74)	15.38	(.75)	15.18	(.76)	15.04	(.72)
Faculty: Hours teaching and advising	10.42	(.91)	10.65	(1.01)	10.88	(.94)	10.94	(.93)
Faculty perception: Student competition	2.18	(.32)	2.13	(.34)	2.05	(.33)	2.01	(.31)
College experiences								
Satisfaction: Science and math courses	4.19	(.82)	4.23	(.78)	3.71	(.89)	3.66	(.90)
Academic interaction with classmates	4.80	(.99)	4.73	(.99)	4.54	(1.0 1)	4.73	(1.00)
Received tutoring in courses	1.22	(.44)	1.21	(.44)	1.21	(.43)	1.19	(.42)
Tutored another student	1.83	(.65)	1.90	(.70)	1.66	(.63)	1.58	(.63)
# Math/science courses in college	17.65	(4.46)	16.58	(4.57)	8.88	(5.17)	7.80	(4.70)
College grades	4.24	(1.07)	4.45	(1.03)	4.08	(1.06)	4.28	(1.00)
Worked on independent research project	1.80	(.81)	1.80	(.84)	1.80	(.78)	1.77	(.80)
Felt overwhelmed	2.14	(.61)	2.33	(.56)	2.12	(.60)	2.34	(.56)
Interacting with faculty	6.34	(1.49)	6.80	(1.50)	6.42	(1.53)	6.45	(1.50)