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MATHEMATICAL SELF-CONCEPT: How College Reinforces the Gender Gap

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Research in the past decade suggests that persistent gender gaps in math achievement may be rooted in gender differences in math self-concept. Yet, limited research exists on how students' math self-concept develops, and whether this differs between men and women. Using a sample of 8,997 women and 6,053 men, this study examines the factors associated with the development of women's and men's mathematical self-concept during college. Findings reveal a number of student background characteristics and college environments and experiences that contribute to an overall decline in math self-concept during college, and show how college reinforces the gender gap in math confidence. Additionally, in an attempt to answer the perennial question of whether it is "better to be a big frog in a small pond or a small frog in a big pond," the study pays special attention to the relationship between institutional selectivity and math self-concept. Although institutional selectivity is correlated with declines in math self-concept, results show that specific *aspects* of selective environments, rather than selectivity itself, are more important predictors of math self-concept.

Gender differences in math achievement are a continuing source of concern among educators. Past research has shown that even after controlling for common sources of gender differences (i.e., attitudes toward math, exposure to math-related courses, etc.), women continue to score lower on tests of math ability (Benbow and Stanley, 1982; de Wolf, 1981; Ethington and Wolfle, 1984). Explanations for this persistent discrepancy are numerous: gender bias in math tests (de Wolf, 1981), the perception that math is a "masculine" pursuit (Selkow, 1985), biological differences between men's and women's cognitive capabilities (Kimura, 1992), and continuing stereotypes of girls as less able in math (Meece et al., 1982). Research in the past decade suggests that women are simply less confident in math, and that this difference in self-concept results

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in differences in math achievement (Ethington, 1988; Marsh, Smith and Barnes, 1985; Meece et al., 1982; Sherman, 1982). Indeed, mathematical self-concept has been shown to be a positive predictor of persistence in math (Sherman, 1983), as well as performance on tests of math achievement (Astin, 1993). Similarly, a large number of studies provide evidence that overall academic self-concept may be causally linked to academic achievement (Bailey, 1971; Byrne, 1984; Hansford and Hattie, 1982).

An understanding of the causes of the gender gap in math ability thus necessitates a study of what factors influence mathematical self-concept, and how these may differ between women and men. The purpose of this study is to examine the personal and environmental factors associated with the development of mathematical self-concept during college. This study attempts to move beyond previous research, first by focusing specifically on mathematical self-concept, rather than on overall measures of academic self-concept, and second by describing how math self-concept develops differently in men and women. If the assumption is valid that self-concept is causally linked to academic achievement, then perhaps findings from this study will ultimately aid in reducing the gender gap in math performance.

BACKGROUND OF STUDY

Given the importance placed on self-concept as an achievement predictor, reports of gender differences in math self-concept are especially meaningful. Over time, women have expressed less self-confidence in their math abilities than have men (Astin, 1978; MacCorquodale, 1984). In the precollege years, gender differences in math self-concept are reported to increase as students become older (Hyde et al., 1990; Meece et al., 1982). During college, while math self-confidence declines for both men and women (Astin, 1977, 1993; Drew, 1992), women continue to exhibit less confidence in math than do men (Higher Education Research Institute [HERI], 1991). Similarly, studies that include math self-confidence within an overall indicator of academic self-confidence report that the impact of college is to reinforce the gender gap in academic self-concept (Astin, 1977; Smart and Pascarella, 1986).

Why is it, then, that women express less math self-confidence than do men? Do men and women merely *perceive* their math abilities differently, or are their perceptions accurate reflections of differences in ability? Caporrimo (1990) suggests that women are more reluctant to voice confidence in math because they have been socialized in a system that discourages the development of women's mathematical confidence. Even when women perform slightly better than men on tests of math ability, men are reported to express higher levels of math self-confidence (Marsh, Smith, and Barnes, 1985; Sherman, 1983). Similarly, in a comparison of college students' math self-concept estimates with actual SAT math scores, Drew (1992) found women more likely than men to underestimate their math abilities. It thus appears that math self-concept may be a function of factors other than actual math ability.

Factors Influencing Self-concept

Although few studies have looked specifically at mathematical self-concept, research conducted by Astin, Pascarella, and others has utilized mathematical self-concept as a component of academic or intellectual self-concept factors. These studies describe a number of student characteristics, educational environments, and experiences that influence students' academic self-concept, and thus may shed light on the factors predicting math self-concept.

Among precollege characteristics, positive predictors of academic self-concept include degree aspirations (Smart and Pascarella, 1986) and high school achievement and socioeconomic status (Astin, 1993; Pascarella et al., 1987), while being female has been shown to be a negative predictor of academic self-concept (Astin, 1993; Pascarella, 1985a). In studies related specifically to math self-concept, verbal achievement has shown to be a negative predictor of mathematical self-concept for elementary students (Marsh, 1986; Marsh, Smith and Barnes, 1985).

College environments and experiences that have been associated with increases in academic self-concept include majoring in math, physical science, or engineering (Astin, 1977), interacting with faculty (Astin, 1993, Pascarella, 1985a, 1985b), interacting with other students (Astin, 1993; Pascarella et al., 1987; Pascarella, undated), college grades (Smart and Pascarella, 1986; Pascarella et al., 1987), tutoring other students (Astin, 1993), and for men only, institutional size (Smart and Pascarella, 1986). Finally, attendance at a public college was shown to be related to declines in intellectual self-esteem (Astin, 1993; Pascarella et al., 1987).

School Selectivity as a Predictor of Self-concept

Among studies attempting to describe the factors that affect students' self-concept, the peer environment has received much attention. Reitz's (1975) conclusion that "colleges as normative reference groups influence absolute self-assessments" is a common theme in research attempting to define the relationship between the student and his or her academic environment. Indeed, a number of models have developed describing the effect that peer ability level has on students' self-concept and aspirations. Prominent among these are *relative deprivation, environmental press,* and *internal/external frame of reference.*

A basic tenet of the relative deprivation theory is that it is "better to be a big frog in a small pond than a small frog in a big pond." In other words, regardless of actual ability, a student will feel more academically confident among a relatively lower-ability peer group than among a higher-ability grouping. Applicability of the relative deprivation theory to education was first elaborated by Davis (1966), in a study of the effect of college selectivity on the career decisions of men. He found that since college selectivity is negatively related to college grades, and since college grades are positively related to career aspirations, attending a highly selective school ultimately lowers men's career aspirations. In validating the theory of relative deprivation, Davis concluded that self-concept is formed by comparing oneself to others, and that comparison groups among college students are those on one's campus; therefore, attending a more selective college ultimately reduces one's academic self-concept.

The environmental press theory also rests on the assumption that students will compare themselves to their peers, yet this model asserts that students will take into account their school's selectivity, as compared with other schools, when making self-assessments. In other words, merely being accepted to or enrolled in a selective college will boost students' academic confidence. As elaborated by Bassis (1977), "A given grade earned by a freshman at a highly selective college is likely to produce more positive changes in his self-evaluation than that grade at a less selective college."

Numerous studies have attempted to determine the validity of both relative deprivation and environmental press. Pascarella and Terenzini (1991) suggest that while most research tends to support relative deprivation, there has not been enough conclusive evidence either way. In studies of educational aspirations, Drew and Astin (1972) and Patterson (1976) found support for both theories, while Werts and Watley's (1969) study tended to support relative deprivation. Support for environmental press is found in studies by Thistlethwaite and Wheeler (1966) and Pascarella (1985a), which report positive effects of college selectivity on educational aspirations.

Self-concept research has yielded similarly inconsistent results. Pascarella's (undated) finding that selectivity has a negative effect on the intellectual self-concept of women, but not men, lends some support to the relative deprivation argument. However, support for environmental press may be extracted from studies by Astin and Kent (1983) and Smart and Pascarella (1986), who report selectivity to be a positive predictor of academic self-concept. The Astin and Kent study, however, found this relationship to hold true only for men. In a study of academic self-evaluation, Bassis (1977) found partial support for both relative deprivation and environmental press. Finally, Astin (1977) and Pascarella et al. (1987) report no direct effects of selectivity on academic self-concept.

The inconsistency of findings regarding relative deprivation and environmental press lends support for a relatively recent model, which combines elements of the previous theories. The internal/external frame of reference model

(Marsh, 1986) suggests that, in making math self-assessments, students will rate their math ability in comparison with their own verbal ability (internal), and will also compare their math skills with their perception of others' math skills (external). In other words, math self-concept is enhanced when students rate their math ability higher than their verbal ability, and when they believe that their math ability is higher than that of their peers. Marsh and his colleagues have tested this model with primary school students and have concluded that academic self-concept, for both males and females, is determined by both the ability of the student and the ability of the peer group (Marsh, 1984a, 1984b; Marsh and Parker, 1984; Marsh, Smith, and Barnes, 1985).

OBJECTIVES

While previous research has tended to include math self-confidence as a component of overall academic self-concept, it is also important to study mathematical self-concept as a separate outcome of college. Although math self-concept may be highly correlated with other measures of self-concept, it is also a "distinct" component of self-concept (Shavelson and Bolus, 1982). This is underscored by the fact that math self-confidence declines during college while academic self-confidence confidence increases (HERI, 1991).

Informed by Shavelson, Hubner, and Stanton's (1976) definition of self-concept as "a person's perception of himself . . . formed through his experience with his environment . . . and influenced especially by environmental reinforcements and significant others," this study describes differences in how college men and women perceive their math abilities, as well as what factors contribute to the development of this perception. Specifically, the study examines men's and women's mathematical self-rating as they enter college, as well as how and why this self-rating may change during the four years after college entry. Additionally, although this study does not provide a stringent test of relative deprivation, environmental press, and internal/external frame of reference, the validity of these models is addressed as this study examines how math self-concept development is related to institutional selectivity, as well as to students' math and verbal abilities.

METHODOLOGY

Sample

The data in this study are drawn from the Cooperative Institutional Research Program (CIRP) 1985 Freshman Survey and 1989 Follow-Up Survey, which are sponsored by the American Council on Education and the UCLA Higher Education Research Institute (HERI). Data collection was also made possible through grants from the Exxon Education Foundation and the National Science Foundation. These data include information from over 27,000 college freshmen who were followed up four years later, and incorporate information acquired directly from institutions, as well as information from nineteen other sources, including the 1989–90 HERI Faculty Survey, the 1989 HERI Registrar's Survey, and HEGIS Opening Fall Enrollments. The sample in this study is limited to 15,050 students (8,997 women; 6,053 men) attending 392 four-year colleges and universities. A "maximum contribution" limit was imposed on institutions so as to prevent any institution from contributing more than one percent to the final sample. A complete description of sampling and weighting procedures is provided in HERI (1991).

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' high school math preparation, be controlled in order to obtain a relatively unbiased measure of the effect of the college "environment" on specific cognitive or affective "outcomes."

First, changes in men's and women's mathematical self-rating over the four years after college entry are examined through means and cross-tabulations. Second, four-year changes in self-concept for men and women are displayed by level of institutional selectivity. Next, blocked stepwise regression analyses were performed separately for men and women in order to explore which student background characteristics and college environments and experiences contribute to the development of mathematical self-confidence during college. In light of the large number of variables included in analyses, tolerance protection was set at .30 to guard against potential problems resulting from multicollinearity.[1]

Variables

The dependent variable used in this study is students' self-rating of their mathematical ability four years after college entry. Respondents were asked to rate their own mathematical ability as compared to "the average person your age" on a five-point scale: "highest 10 percent," "above average," "average," "below average," and "lowest 10 percent." In accordance with the I-E-O model, independent variables were blocked in the temporal sequence in which they may have had an effect on students' math self-concept: (1) input characteristics, (2) choice of major, (3) college environments, and (4) college experiences. (See Appendix A for a complete list of variables and coding schemes.)

Input characteristics include background measures, such as parental income and mother's and father's educational level, as well as characteristics of the students before or at the point of college entry that might affect math self-concept development during college, such as SAT scores, high school math and science preparation, and initial academic self-concept.

The second set of variables, students' intended choice of college major, can be interpreted as a "bridge" between student inputs and college environments, since the initial choice of college major 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 include structural characteristics of institutions (selectivity, size, type, and control), as well as characteristics of peer and faculty environments that might serve to mediate the development of math self-concept during college. Three aspects of the peer group are included in order to measure how the math and science orientation as well as the intellectualism of the peer group might influence how students rate their own math ability: peer high school science preparation, peer enrollment in college math and sciences courses, and peer intellectual self-esteem. An additional aspect of the peer group, percent enrollment of women, is included in order to analyze how institutional sex ratio might affect math self-concept for women or men. Of the two faculty-derived measures, one actually serves to represent an additional characteristic of the peer group: the perception among faculty that students engage in competition for high grades. Inclusion of this measure is based on the assumption that students might be more critical of their own ability in a highly competitive environment. Finally, the amount of time faculty spend teaching and advising is included in order to assess whether math self-concept is enhanced in an environment oriented toward student learning and development.

The last block of environmental variables includes measures of student involvement and experiences in college that have been shown to enhance academic or math self-concept (as described in the review of literature): number of math and science courses, satisfaction with math and science courses, interaction with faculty, tutoring other students, and college grades. The present study explores three additional aspects of the college experience that might have an effect on students' math self-concept: working on an independent research project, receiving tutoring in courses, and feeling overwhelmed. Because previous research has not analyzed the effect of these experiences on students' math self-concept, it is useful to include such measures as they might relate to how students perceive themselves and their abilities. It is expected that students who engage in independent research will gain confidence in their abilities, whereas those who receive tutoring or who experience high academic stress levels are expected to experience relative declines in math self-concept.

This last block of variables is not included in the environmental block because while the experiences one has after entering college constitute part of the "environment" to which one is exposed, these experiences are also *dependent*, to some extent, on the type of institution attended. This block is therefore included in a block *after* the effects of the other college environmental measures have been controlled. However, since the temporal ordering of college experiences and the dependent variable cannot be firmly established (both are measured in the follow-up questionnaire), we cannot be certain that a partial correlation between any college experience and the dependent variable reflects a causal relationship. Consequently, interpretation of the "effects" of such college experiences is necessarily tenuous.

RESULTS

Consistent with the results of previous studies, women exhibit initially lower self-ratings of their mathematical abilities than do men. In a comparison of mean math self-concepts for men and women, Table 1 shows that upon college entry, men's mathematical self-ratings tend toward "above average," while women's self-ratings are closer to "average." Table 1 also reveals a substantial gender gap between the percentages of men and women who are highly confident with their math skills: one in four men (24.4 percent) rated themselves as being in the "highest 10 percent" of math ability, versus one in ten among the

TABLE 1. Changes in Mathematical Self-Rating for Men and Women During College (Male n = 6,053; Female n = 8,997)

	1985		1989		Percent Change	
Self-Rating	Men	Women	Men	Women	Men	Women
Highest 10%	24.4	10.8	20.9	8.7	−3.5	−2.1
Above average	37.5	35.3	37.6	32.5	+0.1	−2.8
Average	26.9	36.1	28.4	38.3	+1.5	+2.2
Below average	9.6	14.4	11.5	17.6	+1.9	+3.2
Lowest 10%	1.6	3.4	1.6	2.9	0.0	−0.5
Mean	3.74	3.36	3.65	3.26	−.09	−.10
(S.D.)	(.98)	(.97)	(.98)	(.95)		

Note: Chi-square tests indicate statistically significant gender differences ($p < .0001$) in both 1985 and 1989.

women freshmen (10.8 percent). Similarly, a greater percentage of women than men designate themselves as "below average" or "lowest 10 percent" in math ability (17.8 percent, versus 11.2 percent for men).

Four-year changes in mathematical self-rating reveal that mean declines are similar for men and women. However, the proportional loss of students rating themselves "above average" or in the "highest 10 percent" is greater among women. This finding is disturbing in two respects. First, our most confident students in math are becoming less mathematically confident during college, and second, this effect is stronger for women.

Table 2 shows how math self-confidence changes at various levels of institutional selectivity (defined as institutional mean on the SAT [Verbal + Math]). As would be expected, both men's and women's precollege math self-ratings are higher in the more selective colleges, and at each level of selectivity, men express greater initial math self-confidence than do women. Four-year changes reveal overall declines in students' math self-concept within all levels of selectivity. Interestingly, the magnitude of the decline is greater in more selective schools.

These findings lend support to the theory of relative deprivation by revealing that students who enroll in more selective colleges experience greater declines in the perception of their own math abilities. Additionally, the decline in math self-confidence in selective colleges is more pronounced for women than for men. This finding suggests that women might be more strongly affected than men by a sense of "relative deprivation" with respect to math ability.

Although these analyses show that men and women experience differential changes in math self-confidence within varying levels of institutional selectivity, means and cross-tabulations alone cannot provide conclusive evidence on the impact of this college environment. The goal of the regression analyses that follow will be to help explain whether these changes can actually be attributed to selectivity, or whether input variables or specific aspects of selective environments are the determining factors.

Regression Analyses

Tables 3 and 4 provide a list of the variables that entered the separate regression equations for women and men, as well as corresponding simple correlations and standardized regression coefficients (betas). In order to show how the effect of each variable changes as other variables are controlled, regression coefficients are reported at the step after inputs are controlled and at the final step in the regression equation. Readers interested in how regression coefficients change at *each* step in the equation may contact the author.

Table 3 shows that the pretest (1985 mathematical self-rating) is highly predictive (r = .67) of women's 1989 math self-rating. The strength of this rela-

TABLE 2. Mathematical Self-Rating for Men[a] and Women[a] in Institutions with Low, Medium, and High Selectivity[b] (in percentages)

	Low Selectivity						Medium Selectivity						High Selectivity					
	1985		1989		Change 1985–1989		1985		1989		Change 1985–1989		1985		1989		Change 1985–1989	
Self-Rating	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W	M	W
Highest 10%	14	7	12	7	−2	0	20	10	18	8	−2	−2	40	17	34	12	−6	−5
Above average	33	30	36	29	+3	−1	40	35	38	33	−2	−2	38	45	37	38	−1	−7
Average	36	39	34	41	−2	+2	27	38	30	38	+3	0	17	28	21	35	+4	+7
Below average	15	19	16	19	+1	0	11	14	12	18	+1	+4	4	9	7	14	+3	+5
Lowest 10%	3	5	2	4	−1	−1	2	3	2	3	0	0	1	1	1	1	0	0
Mean	3.42	3.15	3.39	3.14	−.03	−.01	3.66	3.35	3.58	3.26	−.08	−.09	4.12	3.67	3.96	3.46	−.16	−.21
(S.D.)	(.98)	(.98)	(.96)	(.94)			(.98)	(.95)	(.98)	(.94)			(.89)	(.91)	(.95)	(.91)		

Note: Chi-square tests indicate statistically significant gender differences ($p < .0001$) within each level of selectivity.

[a]Sample sizes: Low selectivity: Men (1,262), Women (2,428); Medium selectivity: Men (2,778), Women (4,142); High selectivity: Men (1,705), Women (1,869).

[b]Selectivity is defined as institutional mean SAT verbal + SAT math. Low selectivity = 400–970; medium selectivity = 980–1130; high selectivity = 1140–1600.

TABLE 3. Predictors of Mathematical Self-Rating for Women (Standardized regression coefficients, $N = 8{,}316$)

Variable	Simple r	Beta After Inputs[a]	Final Beta
Input Characteristics			
1985 mathematical self-rating	.67	.57***	.51***
SAT math	.39	.19***	.18***
SAT verbal	.12	−.15***	−.11***
Years of high school math/science	.25	.05***	.02
Scientific orientation[b]	.15	.04***	.00
Average high school grades	.30	.04***	.01
Father's education	.03	−.04***	−.03*
College Major			
Engineering	.20	.07***	.05***
Business	.08	.06***	.07***
Arts/humanities	−.15	−.06***	−.02
Physical science	.17	.03**	.02
Vocational/technical	.06	.02*	−.03**
Social sciences	−.12	−.04***	.00
College Environments			
Faculty perception: competition among students	.12	−.04***	−.03**
Percent women	−.05	.02	.03**
College Experiences			
Number of math/science courses	.40	.19***	.15***
Satisfaction with math/science courses	.27	.14***	.10***
Tutored another student	.17	.07***	.05***
Felt overwhelmed	−.06	−.03***	−.03**
Student-faculty interaction[b]	.03	−.00	−.03**

Note: Variables listed are those that entered the regression equation at $p < .001$.
[a]Except for coefficients corresponding to input characteristics, beta coefficients in this column represent the standardized regression coefficient that variable would have received if it had entered at the step immediately after inputs are controlled.
[b]See Appendix B for description of factor.
$^{*}p < .01$, $^{**}p < .001$, $^{***}p < .0001$.

tionship is remarkable, considering that this is a single item answered on a five-point scale, and that there is a gap of four years between pretest and posttest. Although a number of other student characteristics, experiences, and college environments contribute to women's math self-rating four years after college entry, none can match the predictive power of these students' confidence in their math abilities *before* entering college.

Once controlling for women's initial math self-confidence. the strongest positive predictor of 1989 math self-rating is SAT math. Regardless of their initial confidence in math, women scoring higher on SAT math are more likely to increase their mathematical confidence during the college years. Interestingly, while SAT verbal is positively correlated with women's math self-rating, scores on this test appear to have a *negative* effect on their 1989 self-rating. In other words, once the positive relationship between SAT math and math self-rating is controlled, higher SAT verbal scores are in fact negatively related to 1989 math self-confidence. Among other things, this finding suggests that students tend to rate their math ability in part in terms of the *discrepancy* between math and verbal skill levels. Verbal ability apparently becomes a kind of "frame of reference" such that a discrepancy in favor of math enhances math self-rating, while a discrepancy in favor of verbal scores depresses the math self-rating.

Three input characteristics entering this regression reflect the positive contributions of academic preparation and interest in science in the development of women's math self-confidence: the number of years of high school math and science taken, high school grades, and having a precollege scientific orientation. The only other input characteristic with an effect on women's math self-confidence is level of father's education. Interestingly, the simple correlation between father's education and 1989 math self-rating is positive, yet the resulting regression coefficient is negative. This suggests that while women with more highly educated fathers are likely to have higher math self-ratings, once the effects of initial math self-ratings are controlled, having a highly educated father actually results in slightly lower math self-ratings.

Women majoring in the following four fields are more likely to gain confidence in math during college: engineering, business, physical sciences, and vocational/technical majors (i.e., electronics, mechanics, data processing). Alternatively, women who major in the arts and humanities or in the social sciences are more likely to reduce their confidence in math during college, although the effects of majoring in the social sciences disappear once college environments and experiences are controlled. Overall, these findings show that women who persist in a more mathematically oriented curriculum tend to gain confidence in their math abilities during college.

Among the twelve college environmental variables included in the analyses, two appear to have a modest effect on women's mathematical self-concept. First, competition among students (as perceived by faculty) has a negative effect on women's math self-rating. Although the simple correlation between competitiveness and women's math self-rating is positive (indicating that women with higher math self-concepts are likely to be enrolled in more competitive schools), competitiveness appears to have a negative *impact* on women's mathematical self-confidence. The second college environmental variable impacting women's math self-confidence is the percentage of women enrolled. Similar to the finding for competitive environments, there is a sign reversal between the simple correlation and the final regression coefficient. In this case, the negative simple correlation implies that women attending institutions with greater percentages of women are likely to have lower math self-ratings. Yet, once women's initially lower math self-confidence is controlled, attending an institution with greater percentages of women appears to have a positive *effect* on women's math self-confidence. Overall, these findings suggest that women may be better served by environments that are either noncompetitive or in which they are surrounded by a greater percentage of female peers.

Looking at college experiences contributing to women's math self-concept, we find that the number of math and science courses taken and the level of satisfaction with these courses both have positive effects on women's math self-rating. These findings are not surprising, as greater exposure to and satisfaction with college math and science would be likely to enhance mathematical self-confidence. Interestingly, though, tutoring another student came in as the next strongest predictor among the eight college experiences included in the analyses. Women who tutored other students during college showed higher than expected gains in mathematical self-confidence. Although we do not know specifically in which subjects these women were tutoring, this finding reflects the benefits that have been associated with being a peer tutor (Bargh and Schul, 1980). By contrast, the experience of feeling "overwhelmed" during college has a slight negative relationship with women's math self-confidence. While feeling overwhelmed may not be a direct causal factor leading to decreased math self-concept for women, it is important to know that a link exists between emotional well-being and mathematical self-concept.

A rather surprising finding is that interaction with faculty is associated with a decline in mathematical self-concept among women. Although the simple correlation between interaction with faculty and math self-confidence is positive, once the effects of initial math self-rating, and enrollment in and satisfaction with math and science courses are controlled, greater interaction with faculty ultimately has a small negative effect on women's self-confidence in math. This finding can perhaps be interpreted not as evidence that interaction with faculty is detrimental to women, but as an implication that the *type* of interaction that currently exists between women students and faculty may have a negative effect on women's mathematical self-confidence. While it may be that women who experience difficulty with math are more likely to seek help from faculty (hence greater interaction), only one item on the student-faculty interaction factor refers specifically to talking with faculty outside of class (see Appendix B). The remaining three items reflect activities one would *not* typically associate with having difficulties with math (being a guest in a professor's home, working on a professor's research project, and assisting faculty in teaching a class).

Table 4 provides a list of the variables that entered the regression equation for men, as well as corresponding simple correlations and standardized regression coefficients. Four of the input characteristics having an effect on men's math self-confidence are the same as those that entered the regression for women. As was found for women, a substantial correlation exists between pretest and posttest measures of men's math self-rating ($r = .70$). While SAT math and scientific orientation are associated with gains in math self-confidence for men, the effects of having a scientific orientation become slightly negative once college environments and experiences are controlled. Finally, mother's education was found to affect men in much the same way that father's education appeared to affect women. While there is a positive simple correlation between mother's education and men's math self-rating, the *effect* of having a

TABLE 4. Predictors of Mathematical Self-Rating for Men (Standardized regression coefficients, $N = 5{,}679$)

Variable	Simple r	Beta After Inputs[a]	Final Beta
Input Characteristics			
1985 mathematical self-rating	.70	.59***	.51***
SAT math	.50	.22***	.18***
SAT verbal	.23	−.08***	−.07***
Scientific orientation[b]	.21	.06***	−.01
Mother's education	.05	−.04***	−.03**
College Major			
Engineering	.28	.08***	.02
Social sciences	−.14	−.07***	−.04***
Arts/humanities	−.15	−.05***	−.03*
College Environments			
Public university	.03	−.02	−.03*
College Experiences			
Number of math/science courses	.48	.22***	.18***
Satisfaction with math/science courses	.29	.14***	.09***
Average undergraduate grades	.22	.05***	.04***

Note: Variables listed are those that entered the regression equation at $p < .001$.
[a]Except for coefficients corresponding to input characteristics, beta coefficients in this column represent the standardized regression coefficient that variable would have received if it had entered at the step immediately after inputs are controlled.
[b]See Appendix B for description of factor.
*$p < .01$, **$p < .001$, ***$p < .0001$.

highly educated mother is actually negative once the math abilities and initial self-confidence of these students are controlled.

Among college majors, only engineering entered as a positive predictor of men's math self-confidence. Majors associated with declines in men's math self-confidence include the social sciences and the arts and humanities.

The only environmental variable having a significant effect (a slight negative effect) on men's math self-rating is attending a public university. This finding is consistent with findings made by Astin (1993) and Pascarella et al. (1987) that students attending public colleges are more likely to experience declines in intellectual self-esteem.

Finally, as would be expected, findings related to college experiences suggest that men who receive higher grades, continue with math and science during college, and are satisfied with their experience within these courses stand a better chance of gaining confidence in math.

Comparing Results for Men and Women

Table 5 compares unstandardized regression coefficients for the variables entering the equations for men and women.[2] Among the total of forty-two independent variables included in analyses, nine enter regression equations for both men and women, while an additional thirteen variables enter for one group or another. Interestingly, although fewer variables enter the regression for men, these variables account for a slightly greater proportion of the variance in men's math self-concept than do the variables entering for women. (For men, twelve variables account for 56.1 percent of the variance in math self-rating, while twenty variables account for 52.3 percent of the variance for women.)

Input characteristics that have similar effects for both men and women include: 1985 math self-rating, SAT math and verbal scores, and having a scientific orientation. The positive effects of the number of years of high school math and high school grades appear to be significant only for women. Perhaps specific high school experiences, such as receiving good grades and taking more math and science courses, are more important contributors to math self-confidence for women than for men.

Once other inputs have been controlled, level of parental education has a slightly negative effect on both men's and women's math self-concept; however, each group is apparently affected by the parent of the opposite sex. An interpretation of these cross-gender effects rests on an assumption that clearly requires further investigation. This assumption is that if men and women were asked to compare their math ability to the overall math ability of the group of the opposite sex, men would generally rate themselves superior to women, and women would generally see themselves as less able in math than men. If this assumption holds, then perhaps men with highly educated mothers would not

TABLE 5. Comparison of Predictors of Mathematical Self-Rating for Men and Women (Unstandardized regression coefficients)

	Men (N = 5,679)		Women (N = 8,316)	
	b after Inputs[a]	Final *b*	*b* after Inputs[a]	Final *b*
Input Characteristics				
1985 mathematical self-rating	.560	.506	.530	.497
SAT math	.002	.002	.002	.002
SAT verbal	−.001	−.001	−.001	−.001
Scientific orientation	.036	−.011	.038	−.006
Years of high school math/science	(.009)	(.000)	.020	.009
Average high school grades	(.013)	(.018)	.024	.007
Mother's education	−.017	−.016	(−.004)	(−.005)
Father's education	(−.001)	(−.001)	−.014	−.011
	(R^2 = .511)		(R^2 = .472)	
College Major				
Engineering	.157	.050	.345	.219
Social sciences	−.246	−.143	−.078	.000
Arts/humanities	−.202	−.108	−.143	−.053
Business	(.036)	(.110)	.138	.165
Physical science	(.089)	(.007)	.179	.098
Vocational/technical	(.063)	(.007)	.295	.272
	(R^2 = .522)		(R^2 = .485)	
College Environments				
Public university	−.085	−.071	(−.045)	(−.034)
Faculty perception: competition among students	(−.058)	(−.063)	−.115	−.087
Percent women	(.001)	(.002)	.002	.001
	(R^2 = .524)		(R^2 = .487)	
College Experiences				
Number of math/science courses	.032	.028	.032	.027
Satisfaction with math/science courses	.143	.096	.140	.105
Average undergraduate grades	.059	.040	(.039)	(.019)
Tutored another student	(.098)	(.041)	.100	.077
Felt overwhelmed	(−.027)	(−.023)	−.054	−.048
Student-faculty interaction	(.009)	(−.018)	.005	−.019
	(R^2 = .561)		(R^2 = .523)	

Note: Coefficients in parentheses correspond to variables that did not enter the regression equation for that group. In these cases, *b*s represent the regression coefficient that variable would have received if it entered at the *next* step.

[a]Except for coefficients corresponding to input characteristics, coefficients in this column represent the unstandardized regression coefficient that variable would have received if it had entered at the step immediately after inputs are controlled.

be as overconfident as other men, because they have contact with, and are influenced by, highly educated, intelligent women. In other words, although men with highly educated mothers have overall greater confidence in math, these men might be less likely to *overestimate* their math abilities. Similarly, since women may already feel inferior to men in math ability, having highly educated fathers may reinforce their relatively lower math self-confidence. Again, these explanations rest on an assumption which, although intriguing, merits empirical validation.

Among college majors, three enter as math self-concept predictors for men and women: engineering (+), social sciences (−), and arts and humanities (−). However, the positive effect of majoring in engineering is stronger for women, while the negative effects of majoring in the social sciences or in the arts and humanities are slightly stronger for men (in fact, the effect of social science on women disappears by the last step in the analysis). Three major fields appear to be positively related to math self-confidence for women only: business, physical science, and vocational/technical. Interestingly, the majors that promote math self-concept are in fields that have been traditionally male dominated, while the majors associated with decreases in math self-concept are in fields typically dominated by women. These findings further emphasize gender differences and the potential implications of students' curricular choices.

No college environments enter regression equations for both women and men. Public university attendance has a negative effect for men, while being in a competitive environment results in lower math self-confidence for women. Attending an institution with a greater percentage of women was reported to have a positive effect for women only; however, further investigation has revealed that this variable does become significant in the regression equation for men at a point *after* environmental variables have been controlled.

Among college experiences associated with changes in math self-concept. men and women share only two: the positive effects of the number of math and science courses taken, and satisfaction within math and science courses. For men only, receiving higher grades is associated with gains in math self-confidence. Three additional variables entered for women only: tutoring other students (+), feeling overwhelmed (−), and interacting with faculty (−). A closer look at the regression for men reveals that although a negative relationship exists between interacting with faculty and math self-concept, this relationship does *not* reach statistical significance at $p<.001$. Additionally, although tutoring did not enter the regression equation for men, this variable was in fact significant until college grades were controlled. This implies that tutoring others does enhance men's math self-concept; however, the effects are mediated through the higher grades of those men who tutor.

CONCLUSIONS AND RECOMMENDATIONS

Consistent with findings from previous research, women are less confident than men in their mathematical abilities upon college entry, and this disparity increases during the college years. Higher education is apparently reinforcing the differences that exist between men and women with respect to math self-confidence. This study reveals a number of factors that contribute to the overall decline in math self-confidence during college and shows how college contributes to the persistent gender gap in math confidence.

First, results of this study emphasize the importance of major choice as a determinant of math self-concept. Both male and female students majoring in scientific or technical fields experience overall gains in math self-confidence, even when their initially higher levels of math confidence are controlled. If math confidence and ability are ultimately valuable to the college graduate of *any* major field, then perhaps colleges need to reexamine the exposure to mathematical topics and problem-solving techniques that is currently required of students in non-math-oriented fields. If students of all majors had continued exposure to math as it relates to their field of study, even those who presently avoid math during college may find that they are more mathematically capable than they had thought.

Interestingly, although institutional selectivity appeared to be associated with changes in math self-concept, selectivity did not enter regressions for either men or women. However, considering the differential changes in math self-rating at various levels of institutional selectivity (Table 2), college selectivity should not be eliminated from discussions of environmental effects. Instead, environments *associated* with selectivity are more important predictors of math self-concept, as suggested by the negative effects of competitive environments and low enrollments of women. In other words, it may be these *aspects* of selective environments (competitiveness, high enrollment of men), rather than selectivity itself, that contribute more powerfully to the decline in math self-concept. Therefore, even though selectivity itself did not enter regression analyses, findings lend support to the relative deprivation argument, and show that the affective benefits of attending selective institutions, as suggested by environmental press theorists, are not witnessed with respect to math self-concept. The internal/external frame of reference model is supported in part through the negative effects of selective environments and SAT verbal scores; however, the model is not fully supported because this study did not directly test the "internal" aspect of this model (that is, students' *comparison* of their math and verbal abilities).

Thus, it seems that selective colleges can help reduce the gender gap in math self-confidence by working to create a more cooperative and welcoming environment, especially for women. Competitive introductory math and science classes designed to "weed out" the less able students could adopt pedagogical styles that encourage women to enroll in and persist in these fields. Tobias (1990) suggests that math and science faculty develop a more cooperative and interactive pedagogy, which would allow students to feel more involved in the learning process, and may have the effect of "reducing" class size. Tobias also believes that more support groups must be formed within college math and science programs, in which students can talk about their experiences and gain advice from upper-division students Ultimately, adjustments within college math and science programs could work to attract and retain women who otherwise would be turned off by the competitive, male-dominated aspect of many of these programs.

The positive effect of tutoring on math self-confidence also merits discussion. Perhaps the cognitive gains resulting from tutoring another student, as reported by Bargh and Schul (1980), also translate into increased self-concept. Alternatively, though, it may be that tutoring others results in self-confidence gains, which in turn enhance students' actual abilities. Whichever the direction of effect, the benefits associated with tutoring other students suggest that peer tutoring programs should become a larger part of college academic programming.

A surprising and slightly disturbing finding is the negative relationship between interaction with faculty and women's math self-confidence. Although this finding contradicts research describing student-faculty interaction as a positive predictor of self-concept (Astin, 1993; Pascarella, 1985a, 1985b), these previous studies differed from the current study because they looked at overall academic or intellectual self-concept, not math self-concept specifically, and because these studies did not differentiate by gender. As discussed earlier in this paper, a recommendation based on the current finding should not be to discourage women's interaction with faculty, but instead to investigate the *nature* of this interaction.

Overall, perhaps the most important policy implications are associated with the influence of the high school experience on students' attitudes toward math and willingness to continue with math. For both men and women, mathematical self-confidence after four years of college is most strongly predicted by factors pertaining to precollege experiences: initial math self-confidence, SAT scores, an initial interest in science, and for women only, having higher grades and greater math and science preparation in high school. Providing students, especially women, with early preparation and encouragement has been a major recommendation in a number of studies and reports (Benbow and Stanley, 1982; Ethington and Wolfle, 1984; Meece et al., 1982; Sherman, 1982, 1983). Echoing previous suggestions, findings from this study suggest that in order to develop students' mathematical self-confidence, all students, and women in particular, should be encouraged to take more math courses in high school, They should receive positive reinforcements for their accomplishments, and should be encouraged to express confidence in their intellectual abilities.

Therefore, while this study was initially aimed at understanding the impact of college on math self-concept, findings suggest that the experiences *before* college are far stronger influences on students' ultimate level of math confidence. However, because the impact of college is essentially to reinforce the decline in math confidence as well as the gender differences that exist before college entry, higher education must share in the responsibility to counteract these trends.

LIMITATIONS

First among limitations in this study is the use of an outcome measure constructed by a single item. While the CIRP database includes eleven pretest and posttest self-rating measures, only one refers specifically to math ability. Although it would have been preferable to incorporate multiple measures of mathematical self-concept (i.e., self-ratings of problem-solving ability, spatial ability, subject area competence, etc.), the high pretest-posttest correlations suggest that this is a reliable measure.

A second limitation relates to the issue of response bias. Because the CIRP 1989 follow-up respondents tend to be of higher academic ability than nonrespondents (HERI, 1991), the impact of college on math self-concept reported in this study may refer primarily to a selective sample of college students. Although this may limit the ability to generalize the findings to the overall college population, past research has shown that even when marginal distributions are biased, the relationships *among* variables tend to be relatively unbiased (Astin and Panos, 1969). Therefore, while the distribution of mathematical self-ratings may be skewed toward higher ratings, the four-year changes, as well as regression analyses, are still likely to be reflections of actual relationships.

Third, because this study analyzes changes occurring during the first four years after college entry, we cannot be confident that the observed declines in math self-concept persist once the student leaves the college environment. Perhaps when students leave college, they once again reassess their math abilities within their specific field of study or employment. Additionally, research should explore the long-term impact of college attendance on the gender gap in math self-confidence. Do women continue to rate themselves lower than men on math ability in the years after college? Ultimately, future research should explore the lasting effects of college on math self-confidence as well as gender differences therein.

Finally, although a primary focus of this study is on differences between men and women, the study does not differentiate between students of various racial and ethnic groups. Considering the differences among factors predicting men's and women's math self-concept, it is important to investigate whether further differences exist between students of various racial or cultural backgrounds. Future college impact research should thus explore the development of math self-concept by gender as well as race and ethnicity.

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APPENDIX A. 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%"
Average high school grades (self-report)	Eight-point scale: 1 = "D," to 8 = "A or A+"
SAT math	Ranges from 200–800
SAT verbal	Ranges from 200–800
1985 degree aspirations	Five-point scale: 1 = "none," to 5 = "Ph.D., Ed.D., M.D., D.O., D.D.S., D.V.M., LL.B., or J.D"
Parental income	Fourteen-point scale: 1 = "less than $6000," to 14 = "$150,000 or more."
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 composite scale 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)
1985 academic ability self-rating	Five-point scale: 1 = "lowest 10%," to 5 = "highest 10%"
College Major	
Arts/Humanities	All dichotomous: 1 = "no," 2 = "yes"
Biological science	
Business	
Education	
Engineering	
Physical science	
Professional (i.e., architecture, nursing, pharmacy)	

APPENDIX A. *(Continued)*

Social science	(major categories generated from list of 81 possible major choices)
Vocational/technical	
Computer science	
Undecided	
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 college	
Private four-year college	
Size	Undergraduate full-time enrollment
Percent women	Percent enrollment of women
Peer science preparation	Peer mean: number of math/science courses taken in high school
Peer intellectual self-esteem	Peer mean: 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 of 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"
Student-faculty interaction	Four-item factor scale (see Appendix B for items)
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. Items Constituting Factor Scales

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

Peer intellectual self-esteem
- Academic ability (self-rating)[3]
- Mathematical 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]
- Be elected to an academic honor society (expectation)[4]

Student-faculty interaction
- Been guest in a professor's home (activity)[5]
- Worked on professor's research project (activity)[5]
- Assisted faculty in teaching a class (activity)[5]
- Talked with faculty outside class (hours per week)[6]

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."

NOTES

1. An anonymous reviewer of an earlier draft of this paper pointed out that another way to analyze the data would be to enter all of the variables into the regression equation as blocks, rather than using stepwise procedures. The concern raised is that stepwise methods can capitalize on the chance entry of variables, which might lead to unwarranted conclusions, especially if independent variables are highly correlated. Accordingly, the analyses were rerun using the recommended method. Because these results were essentially the same as those reported here, and since stepwise methods allow us to examine how regression coefficients change as each variable enters the equation (Astin, 1991), the results of this reanalysis will not be reported in this paper. Interested readers may contact the author in order to obtain the results of this alternate analysis.
2. It should be noted that entry into a regression equation can be a chance occurrence; two highly correlated variables may compete for entry into an equation, but when the first enters, the second is likely to lose significance. This does not, however, imply that the second variable is unimportant. For this reason, Table 5 includes regression coefficients for both groups for variables entering at least one equation.

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