DOCUMENT RESUME

ED 352 899 HE 026 099

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TITLE	Self-Confidence in Math: How and Why Do Men and Women Differ during the College Years? ASHE Annual Meeting Paper.
PUB DATE	1 Nov 92
NOTE	36p.; Paper presented at the Annual Meeting of the Association for the Study of Higher Education (Minneapolis, MN, October 28-November 1, 1992).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	College Mathematics; *College Students; Educational Environment; Educational Experience; Followup Studies; Higher Education; Majors (Students); Mathematics Achievement; Mathematics Anxiety; Mathematics Education; *Mathematics Skills; National Surveys; *Self Esteem; *Sex Differences; Student Attitudes; Teacher Role; Undergraduate Study
IDENTIFIERS	*ASHE Annual Meeting; Mathematics Education Research; Mathematics Readiness

ABSTRACT

This study examined mathematical self-concept of college students and how it may develop differently between men and women. The study used data from a 1985 Cooperative Institutional Research Programs Survey and a follow-up survey in 1989 which included information from over 27,000 college freshmen and . incorporates information acquired directly from institutions. The sample for the study was limited to 15,050 students attending 192 four-year colleges and universities. The data were analyzed in terms of characteristics at entry to college, intended choice of major, characteristics of the college environment, and college experiences. The dependent variable was students' self-rating of their mathematical ability. Findings indicated that women are less confident than men about their mathematical abilities and that this disparity increases during the college years and is in large part based on their self-confidence and preparation during the high school years and on their experiences during college. Choice of major, and certain factors of institutional selectivity were significant factors in women's change in self-concept regarding mathematics ability. In addition, women who tutor other students in math had higher self-confidence. Interaction with faculty was found to have a negative relationship with women's math self-confidence. Appendixes contain further technical information on the study. (Contains 43 references.) (JB)

Self-Confidence in Math: How and Why do Men and Women Differ During the College Years?

A Paper presented at the Annual Meeting of the Association for the Study of Higher Education

Minneapolis, Minnesota
November 1, 1992

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This paper was presented at the annual meeting of the Association for the Study of Higher Education held at the Marriott City Center, Minneapolis, Minnesota, October 29 - November 1, 1992. This paper was reviewed by ASHE and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC collection of ASHE conference papers.

For years, gender differences in math achievement have been a source of concern, and a focus of much research. Even when common explanations for gender differences have been controlled (i.e. attitudes towards math, exposure to math-related courses, etc.), women have continued to score lower on tests of math ability (Benbow and Stanley, 1982; Ethington and Wolfle, 1984; de Wolf, 1981). A number of suggestions have been offered to explain this persistent discrepancy between men's and women's performance in math. Perhaps tests of math ability are biased towards men (de Wolf, 1981); perhaps women's performance in math is influenced by a perception that math is a "masculine" pursuit (Selkow, 1985); perhaps biological differences exist between men's and women's cognitive capabilities (Kimura, 1992); and perhaps throughout years of schooling, women are discouraged by stereotypes of girls as less able in math (Meece, et al., 1982). An explanation offered in a number of studies is that women are simply less confident in math, and that this difference in self-concept results in differences in math achievement (Ethington, 1988; Marsh, Smith and Barnes, 1985; Meece, et al., 1982; Sherman, 1982). Indeed, self-concept may be intrinsically linked to math achievement. For both men and women, 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, In press). 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 constitutes mathematical self-concept, and how this may differ between women and men.

Gender differences in math self-concept

Given the importance placed on self-concept as a predictor of achievement, reports of gender differences in math self-concept are especially meaningful. Over time, women have expressed less self-confidence in their math abilities than men (Astin, 1978; MacCorquodale, 1984). In the pre-college 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 overall levels of math self-confidence decline for both men and women (Astin, In press; Astin, 1977; Drew, 1992), women continue to exhibit less confidence in math than men (Wingard, et al., 1991). Similarly, studies which 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 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 perhaps more reluctant to voice confidence in math because they have been socialized in a system which often discourages the development of women's mathematical confidence. Even when women perform slightly better 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.

School selectivity as a predictor of self-concept

Among studies attempting to describe the factors which affect students' self-concept, the peer environment has received much attention. Reitz' (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/her academic environment. Indeed, a number of theories 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."

Relative Deprivation and Environmental Press

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 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 theory asserts that students will take into account their school's selectivity, as compared with other schools, when making self-assessments (Bassis, 1977). In other words, merely being accepted to or enrolled in a selective college will boost students' academic confidence. As elaborated by Bassis, "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."

A number of studies have attempted to determine the validity of both relative deprivation and environmental press. Pascarella and Terenzini (1991) suggest that while most studies tend 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.

Research performed on self-concept has reported 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, although the Astin and Kent study found this relationship only to hold true for men. Finally, Astin (1977) and Pascarella, et al. (1987) report no direct effects of selectivity on academic self-concept.

Internal/External Frame of Reference

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 positively influenced by students rating their math ability higher than their verbal ability, and by believing that their math ability is higher than that of their peers. Marsh and his colleagues have tested this model with elementary students, and have concluded that for both males and females, academic self-concept is determined by both the ability of the student and the ability of the peer group (Marsh, Smith, and Barnes, 1985; Marsh, 1984a; Marsh, 1984b; Marsh and Parker, 1984).

Additional predictors of self-concept

The various theories that are used to describe the effect of peer ability on students' self-concept and educational aspirations each have their bases of support. However, as a group these theories are not internally consistent, and thus do not fully explain how students' self-concept is influenced. 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 report a number of student characteristics, educational environments and experiences that influence college students' academic self-concept, and thus may shed light on the factors predicting math self-concept.

Among characteristics that can be determined about students before the college experience, positive predictors of the development of academic self-concept include degree aspirations (Smart and Pascarella, 1986), as well as high school achievement and socioeconomic status (Astin, In press; Pascarella, et al., 1987), while being female has been shown to be a negative predictor of academic self-concept (Astin, In press; Pascarella, 1985a). In studies related specifically to math, 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, In press; Pascarella, 1985a; Pascarella, 1985b), interacting with other students (Astin, In press; Pascarella, et al., 1987; Pascarella, undated), college grades (Smart and Pascarella, 1986; Pascarella, et al., 1987), tutoring other students (Astin, In press), and for men only, institutional size (Smart and Pascarella, 1986). Finally, attendance at a public college was shown to be negatively related to the development of intellectual self-esteem (Astin, In press; Pascarella, et al., 1987).

OBJECTIVES

While previous research has included math self-confidence as a component of overall academic self-concept, it is also important to study mathematical self-concept itself as an outcome of college. Although math self-concept is highly correlated with other measures of self-concept, it is a "distinct" component of self-concept (Shavelson and Bolus, 1982). The fact that math self-confidence declines during college while academic self-confidence increases (Wingard, et al., 1991) is reason alone why self-concept in math deserves singular attention.

Using 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 might 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, the study focuses on the effects, if any, of institutional selectivity on the development of men's and women's math self-confidence during college. If selectivity proves to be significant in the development of math self-confidence, perhaps the current study will garner support for at least one of the proposed models of peer influence (Relative Deprivation, Environmental Press, Internal/External Frame of Reference).

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 attempting to understand how math self-concept may develop differently between men and women. An understanding of the different factors which contribute to men's and women's math self-confidence may allow for the formation of specific, self-concept-enhancing recommendations. If in fact 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.

DATA SOURCE AND ANALYTICAL METHODS

The data source used in this study is 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).

This data includes information from over 27,000 college freshmen who were followed up four years later, and incorporates information acquired directly from institutions, as well as information from nineteen data 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 192 four-year colleges and universities. A "maximum contribution" limit was imposed on institutions so as to avoid any institution contributing more than 1% to the final sample. A complete description of sampling and weighting procedures is provided in Wingard, et al. (1991).

This study employs the "Input-Environment-Outcome" (I-E-O) methodological framework, through which we can assess the impact of various college environments and experiences on specific student outcomes, after controlling for students' pre-college characteristics and experiences. Implementation of this model requires that any biasing effects of "input" characteristics, such as students' high school math preparation, be controlled so that one can measure the effect of the college "environment" on any number of cognitive or affective "outcomes" (Astin, 1991). First, crosstabulations were conducted to display changes in men's and women's mathematical self-rating over the four years after college entry. Second, four-year changes in math self-concept for men and women are displayed by level of institutional selectivity. Next, blocked stepwise regression analysis was utilized separately for men and women in order to explore which input and environmental characteristics and experiences may contribute to the development of mathematical self-confidence during college.

VARIABLES

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 (see Appendix 1 for a list of variables and coding schemes). The first set of independent variables includes characteristics of the student that could be determined at the point of college entry: 1985 mathematical self-rating (pre-test), average high school grades, SAT Math, SAT Verbal, 1985 degree aspirations, parental income, mother's education, father's education, years of high school math/science, scientific orientation, and 1985 academic self-rating.

The second set of variables includes students' intended choice of college major. Major choice 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. Major categories include: arts/humanities, biological science, business, education, engineering, physical science, professional (i.e. architecture, nursing, pharmacy), social science, vocational/technical, computer science, and undecided.

Characteristics of the college environment comprise the next set of variables. This block includes: selectivity, institutional type and control (public university, private university, public four-year college, private four-year college), enrollment size, and percent enrollment of women. Three additional environmental variables reflect characteristics of the peer environment, as measured by computing institutional mean responses from students at each college: peer science preparation, peer intellectual self-esteem, and peer math/science courses taken in college. The last two variables in this block are drawn from faculty surveys: number of hours faculty spend teaching and advising, and the degree to which faculty perceive competition among students to exist at their institution.

Finally, a set of college experiences comprises the last block of environmental variables. This group of variables is not included in the previous block because while the experiences one has during college determine the type of environments to which one is exposed, these experiences are also *dependent* upon the type of environment that exists at the college. Therefore, college experiences must be included in a block *after* the effects of the college environment have been controlled. In this way, the blocking order of independent variables should allow us to have controlled for the correlation between college environments and experiences, so that any remaining relationship between these variables and the dependent variable might denote an "effect."

However, because we cannot be certain that a correlation between any college experience and the dependent variable implies a causal relationship, interpretation of the effects of college experiences is necessarily tenuous. College experiences included in analyses are: number of math/science courses taken, satisfaction with math/science courses, average undergraduate grades, interaction with faculty, worked on an independent research project, received tutoring in courses, tutored another student, and felt overwhelmed.

The dependent variable used in this study is students' self-rating of their mathematical ability four years after college entry. Respondents are asked to rate their own mathematical abilities as compared to "the average person your age" on a five-point scale: "top 10%," "above average," "average," "below average," and "lowest 10%."

RESULTS

Four years changes in math self-concept

Consistent with the results of previous studies, women exhibit initially lower self-ratings of their mathematical abilities than do men. Table 1 shows that upon college entry, men's mathematical self-ratings are clustered around "above average," while women's self-ratings are clustered around "average." A substantial gender gap exists between the percent of men and women with the highest levels of math self-confidence: 24.4% of college men, and only 10.8% of college women, consider themselves in the top 10% of math ability for people their age.

Four-year changes in mathematical self-rating reveal that while the percent of both men and women who rate themselves above average or in the highest 10% decreases during the college years, the decline in math self-confidence is greater for 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 1
Changes in Mathematical Self-Rating fo Men and Women During College
(Male n=6,053; Female n=8,997)

	1985		1989		Percent Change	
Self-Rating	Men	Women	Men	Women	Men [a]	Women [b]
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

[a] p=.00000
[b] p=.00000

In order to investigate how math self-confidence changes at various levels of institutional selectivity, changes in mathematical self-rating for men and women in low, medium, and high selectivity colleges are described in Table 2. "Low selectivity" denotes institutions in which the average SAT score is in the bottom 25% of institutions in the dataset; "medium selectivity" refers to institutions with the middle 50% range of SAT scores; "high selectivity" colleges are those in which SAT scores are in the top 25% among institutions in the study.

As would be expected, both men's and women's, pre-college math self-ratings are higher in the more selective colleges, and at each level of selectivity, men express greater initial math self-confidence than women. Four-year changes reveal overall declines in the percent of men and women rating themselves above average or in the highest 10% within all levels of selectivity (except for a slight increase in math self-ratings among men in low selectivity institutions). Interestingly, the magnitude of the decline becomes greater in more highly selective schools.

These findings lend support to the theory of relative deprivation by revealing that among students who display initially high levels of math self-confidence, those 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 more highly selective colleges appears to be 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" in regards to math ability.

While the results of crosstabulations alone do not provide conclusive evidence in support of the relative deprivation theory, these analyses do suggest that men and women experience differential changes in math self-confidence within varying levels of institutional selectivity. The task of regression analyses will be to help explain whether these changes are actually due to selectivity, or whether specific aspects of selective environments are the determining factors.

Table 2

Mathematical Self-Rating for Men[a] and Women[a] in Low, Medium, and High Selectivity[b] Institutions

	Percent in Low Selectivity						Percent in Medium Selectivity						Percent in 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%	13.9	7.2	11.7	6.5	**-2.2**	**-0.7**	20.1	10.2	18.0	8.4	**-2.1**	**-1.8**	39.9	17.2	33.6	12.0	**-6.3**	**-5.2**
Above average	33.4	29.6	36.1	28.7	**+2.7**	**-0.9**	40.0	35.1	38.2	32.6	**-1.8**	**-2.5**	37.8	44.6	37.4	38.4	**-0.4**	**-6.2**
Average	35.7	39.0	33.7	41.4	**-2.0**	**+2.4**	27.4	37.7	30.1	38.3	**+2.7**	**+0.6**	17.2	27.7	21.1	34.8	**+3.9**	**+7.1**
Below average	14.6	18.8	16.3	19.2	**+1.7**	**+0.4**	10.6	13.9	11.9	18.0	**+1.3**	**+4.1**	4.4	9.2	7.0	13.6	**+2.6**	**+4.4**
Lowest 10%	2.5	5.3	2.1	4.2	**-0.4**	**-1.1**	1.9	3.1	1.9	2.8	**0.0**	**-0.3**	0.6	1.3	0.8	1.2	**+0.2**	**-0.1**

[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 refers to those institutions whose average SAT = 400-970; Medium selectivity refers to those institutions whose average SAT = 980-1130; High selectivity refers to those institutions whose average SAT = 1140-1600.
NOTE: Results for each group are significant at p=.00000.

Regression analyses for women and men

Tables 3, 4, and 5 describe the results of regression analyses on math self-confidence performed separately by gender. Table 3 provides a list of the variables which entered the regression equation for women, as well as corresponding simple correlations and standardized regression coefficients (Betas). The pretest (1985 mathematical self-rating) is highly predictive (r=.67) of women's 1989 math self-rating. The strength of this relationship is remarkable, considering that this is a single item answered on a five-point scale, and there is a gap of four years between pre-test and post-test. 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 value 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 their 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, considering that students with higher SAT Verbal scores are also likely to have higher SAT Math scores, 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.

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 preparation, high school grades, and having a pre-college scientific orientation are each positive predictors of women's self-rating in math. The remaining input characteristic having an effect on the development of 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.

Table 3
Predictors of mathematical self-confidence for women
(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 [a]	.03	-.00	-.03**

Variables listed are those which entered the regression equation at $p < .001$.
Beta coefficients represent standardized regression coefficients.
[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 Table A-2 for description of factor.
* $p< .01$, ** $p< .001$, *** $p< .0001$

This suggests that while women with more highly educated fathers are more likely to have higher math self-ratings, once the effects of higher initial math self-ratings and SAT Math scores are controlled, having a highly educated father results in lower math self-ratings than one would *expect* given these women's initially higher math abilities. This is an intriguing finding, and suggests that perhaps women with more educated fathers feel a greater pressure to succeed, and might not feel that they are living up to their father's expectations or achievements.

Women majoring in the following four major fields appear to be more likely to increase their mathematical self-confidence 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 decrease their math self-rating during college, although the effects of majoring in the social sciences disappear once college environments and experiences are controlled. Overall, these findings merely suggest that women taking a more mathematically-oriented curriculum are likely to gain confidence in their math abilities during college.

Among the twelve college environments included in the analyses, two appear to have an 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 a competitive environment and women's math self-rating is positive (implying that women with higher math self-concepts are more likely to be enrolled in more competitive schools) this type of environment appears to have a negative impact on women's mathematical self-confidence. The second college environment 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 regression coefficients. In this case, the negative correlation implies that women at institutions with greater percentages of women are less likely to have high math self-ratings. Yet, once controlling for these women's initially lower math self-confidence, attending an institution with greater percentages of women actually has a positive effect on women's math self-confidence. Overall, these findings suggest that women may be better served by environments that are either non-competitive or in which they are surrounded by a greater percentage of female peers.

Among college experiences contributing to women's math self-concept, the number of math and science courses taken, and the level of satisfaction within these courses have a positive effect on women's math self-rating. These findings are not surprising, as greater exposure to and satisfaction with college math and science are likely predictors of increased 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). The experience of feeling "overwhelmed" during college has a significant 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, clearly a link exists between emotional well-being and measures of academic self-concept.

Finally, greater interaction with faculty is associated with a decrease in mathematical self-concept for 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 negative effect on women's self-confidence in math. This finding can perhaps be interpreted not as evidence that student-faculty interaction is detrimental, but as an implication that the *type* of interaction which currently exists between women students and faculty may have a negative effect on women's mathematical self-confidence.

Table 4 provides a list of the variables which 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, an extremely high correlation exists between pre-test and post-test measures of men's math self-rating (r=.70). SAT math and scientific orientation are associated with gains in math self-confidence for men, however 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 level of mother's education and men's math self-rating, the effect of having a highly educated mother is actually negative once the initially higher math abilities and self-confidence of these students is controlled.

Table 4
Predictors of mathematical self-confidence for men
(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***

Variables listed are those which entered the regression equation at $p < .001$.
Beta coefficients represent standardized regression coefficients.
[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 Table A-2 for description of factor.
* p< .01, ** p< .001, *** p< .0001

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

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

Among college experiences contributing to men's mathematical self-confidence, the number of math and science courses taken, satisfaction with math and science courses, and undergraduate grades, each appear to have a significant positive relationship with men's rating of their math ability. As would be expected, men who receive higher grades, continue with math and science during college, and are satisfied with their experience within these course stand a better chance of increasing their confidence in math.

Comparing results for men and women

Table 5 compares the unstandardized regression coefficients for the variables entering equations for men and women. Among the total of forty-two independent variables included in the analyses, only nine enter regression equations for both men and women, while an additional thirteen variables enter for one group or the other. Thus, in addition to reporting factors related to math self-concept for all students, this study reveals how the development of self-concept differs between men and women. Interestingly, although fewer variables enter the regression for men, these variables account for a slightly greater percentage of the variance in 1989 math self-concept than the variables entering for women. (For men, twelve variables account for 56.1% of the variance in math self-rating, while twenty variables account for 52.3% of the variance for women).

Table 5
Comparison of predictors of mathematical self-confidence for men and women

	Men (N=5,679)	Women (N=8,316)
Input Characteristics		
1985 Mathematical self-rating	.506	.497
SAT Math	.002	.002
SAT Verbal	-.001	-.001
Scientific orientation	-.011	-.006
Mother's education	-.016	
Father's education		-.011
Years of high school math/science		.009
Average high school grades		.007
	(R^2= .511)	(R^2= .472)
College Major		
Engineering	.050	.219
Social sciences	-.143	.000
Arts/Humanities	-.108	-.053
Business		.165
Physical science		.098
Vocational/technical		.272
	(R^2= .522)	(R^2= .485)
College Environments		
Public university	-.071	
Faculty perception: competition among students		-.087
Percent women		.001
	(R^2= .524)	(R^2= .487)
College Experiences		
Number math/science courses	.028	.027
Satisfaction with math/science courses	.096	.105
Average undergraduate grades	.040	
Tutored another student		.077
Felt overwhelmed		-.048
Student-faculty interaction		-.019
	(R^2= .561)	(R^2= .523)

Variables listed are those which entered a regression equation at $p < .001$.
Coefficients represent unstandardized regression coefficients at the last step in the regression equation.

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.

Both men and women experience a negative effect associated with the level of parental education, however each group is apparently affected by the parent of the opposite sex. An interpretation of these cross-gender effects rests on an assumption which 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 be as over-confident 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 significant 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 stronger for men (in fact, the effect of social science on women disappears by the last step in the analysis). Three majors appear to be positively related to math self-confidence for women only: business, physical science, and vocational/technical. Interestingly, the majors which promote math self-concept are in fields which have been traditionally male-dominated, while the majors which are associated with decreases in math self-concept are in fields typically dominated by women. These findings thus 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 for women, being in a competitive environment results in lower math self-confidence, and being in an environment with a greater percentage of women produces slight gains in math confidence. The fact that this study has found no universal effects of the college environment reinforces the notion that men and women may be differently affected by the college environment.

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 sciences 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. First, women who tutor other students during college show higher than expected gains in math self-concept. Second, greater interaction with faculty is associated with a decrease in math self-concept for women. Finally, women who feel "overwhelmed" by their work report significant decreases in mathematical self-confidence. Overall, college experiences associated with the development of men's math self-confidence are related primarily to classroom experiences and course grades, while women appear to be more strongly affected by experiences outside the classroom.

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 regards to math self-confidence. This study reveals a number of factors which contribute to the overall decline of math self-confidence during college, as well 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 development. While it is logical that students majoring in scientific or technical fields would experience overall increases in math self-confidence, it is also unfortunate that majoring in social science or humanities fields would tend to decrease students' confidence in math, regardless of initial ability. If math confidence and ability is ultimately valuable to the college graduate, 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 mathematical self-rating by gender and institutional selectivity that were reported in 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 public universities, competitive environments, and low enrollments of women. In other words, it may be that *aspects* of selective environments, rather than selectivity itself, which contribute more powerfully to the decline in math self-concept. Therefore, even though selectivity itself did not enter regression analyses, the findings lend support to the relative deprivation argument. The Internal/External Frame of Reference model is supported in part through the negative effects of selective environments, yet the model is not fully supported because this study did directly test the "internal" aspect of this model (that is, students comparison of their math abilities with their 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 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 what they are learning, 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 women's math self-confidence also merits discussion. Women who tutor another student during college are more likely to gain confidence in their own math abilities. 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, In press; Pascarella, 1985a; Pascarella, 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 attention is warranted by the influence of the high school experience on students' attitudes towards 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 pre-college experiences: initial math self-confidence, SAT scores, an initial interest in science, and for women, 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, 1983; Sherman, 1982). Echoing previous suggestions, findings from this study suggest that in order to develop students' mathematical self-confidence, all students, especially women, 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.

Although mathematical self-confidence is only one particular aspect of self-concept, its connection with math performance and achievement, as well as with persistent gender differences, emphasizes the importance of understanding how men's and women's math self-concept can be enhanced. 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 more influential on students' level of math confidence. However, because the impact of college is essentially to reinforce the declines 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 pre-test and post-test 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 use of this particular item nevertheless reveals important information about math self-concept development during college.

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 non-respondents (Wingard, et al., 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 towards 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 decreases 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.

Appendix 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%."
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 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 2 for items).
1985 academic ability self-rating	Five-point scale: 1="lowest 10%," to 5="highest 10%."
College Major	
Arts/Humanities Biological science Business Education Engineering Physical science Professional (i.e. architecture, nursing, pharmacy) Social science Vocational/technical Computer science Undecided	All dichotomous: 1="no," 2="yes." (Major categories generated from list of 81 possible major choices).

Appendix 1 (continued)

College Environments	
Selectivity	Average SAT (or ACT equivalent) of entering freshmen divided by 10.
Public university Private university Public four-year college Private four-year college	All dichotomous: 1="no," 2="yes."
Size	Undergraduate FTE.
Percent women	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 2 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 amongst 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."
Student-faculty interaction	Four-item factor scale (see Appendix 2 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 2
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 (In press).
[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."

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