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AUTHOR Sax, Linda J.
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ABSTRACT

While previous research has outlined factors that can be used to predict academic self-concept among college students, much of this research pays little attention to how self-concept develops differently for unique subgroups of students. This paper examines the development of mathematical self-concept during college for four groups of students who entered college with significantly different levels of math confidence: (1) men in math-intensive majors; (2) women in math-intensive majors; (3) men in non-math-intensive majors; and (4) women in non-math-intensive majors. Data are examined from surveys of over 14,000 college freshmen at 191 institutions who were followed up 4 years after college entry. Regression analyses describe how the factors contributing to the development of math self-concept differentiate among the four groups and suggest how women who persist in math-intensive majors comprise a unique group of students. While the gender gap in math self-concept persists through college for the majority of students, women, as a group, who majored and persisted in math-intensive fields actually gained confidence in math during college. Other characteristics distinguishing this group were: (1) the lack of relationship between the Scholastic Aptitude Test Math score and math confidence 4 years later; and (2) high degree of benefit gained from tutoring other students. On the other hand, interactions by this group (but not by men) with faculty were associated with declines in math confidence. (Contains 29 references.) (Author/DB)

The Development of Mathematical Self-Concept During College: Unique Benefits for Women in Math-Intensive Majors?

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

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Linda J. Sax

Higher Education Research Institute
Graduate School of Education
University of California, Los Angeles

ASHE
ASSOCIATION FOR THE STUDY OF HIGHER EDUCATION

Texas A&M University
Department of Educational Administration
College Station, TX 77843
(409) 845-0393

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Abstract

While previous research has outlined factors that can be used to predict academic self-concept among college students, much of this research pays little attention to how self-concept develops differently for unique sub-groups of students. The purpose of this study is to examine the development of mathematical self-concept during college for four groups of students who entered college with significantly different levels of math confidence: (1) men in math-intensive majors, (2) women in math-intensive majors, (3) men in non-math-intensive majors, and (4) women in non-math-intensive majors. Data were drawn from surveys of over 14,000 freshmen at 191 institutions who were followed up four years after college entry. Regression analyses describe how the factors contributing to the development of math self-concept differentiate among the four groups, and suggest how women who persist in math-intensive majors comprise a unique group of students.

Given the well documented connection between self-concept and achievement (Astin, 1977, 1993; Bailey, 1971; Byrne, 1971; Hansford &Hattie, 1982), the development of academic self-concept among college students merits the attention it has received among higher education research (Astin, 1977, 1993; Komarovsky, 1985; Pascarella, 1985a, 1985b, Pascarella, Smart, Ethington, & Nettles, 1987; Smart & Pascarella, 1986). Yet an informative understanding of the factors associated with academic self-concept development becomes difficult when one considers its many different facets, such as self-concepts in English, history, math, and science (Shavelson, Hubner, & Stanton, 1976). Further, because the development of confidence in a specific field is likely to be related to the exposure a student has to that field, it becomes ever more important to understand how specific academic self-concepts develop differently for students with or without repeated exposure to the subject matter.

This study addresses that issue by analyzing how the development of a specific component of academic self-concept, mathematical self-concept, differs between men and women in fields which rely heavily on the use of math and those in fields which typically require minimal math usage. The choice of math self-concept as the dependent measure is made in part because it is the one measure of academic self-concept that declines during the college years (Astin, 1977, 1993; Drew, 1992), and in part because it is the aspect of academic self-concept that produces the greatest gender differences throughout all levels of education (Astin, 1978; Hyde, Fennema, Ryan, Frost, & Hopp, 1990; MacCorquodale, 1984; Meece, Parsons, Kaczala, Goff, & Futterman, 1982). This study attempts to shed light on whether the factors predicting math self-concept differ depending on students' exposure to math topics and utilities, and additionally whether gender differences in math self-concept vary between students in math/science and non-math/science fields.

Background of the Study

Among academic self-rating measures, self-concept in math ranks near the bottom among college students: while 54.1 percent of college freshmen rate themselves "above average" or in the "highest 10%" in academic ability, only 37.4 percent chose these top categories for mathematical ability (Dey, Astin, Korn, & Riggs, 1992). During the college years, while students gain confidence in their overall academic abilities, their confidence in math has been shown to decline (Astin, 1977, 1993). Additionally, such declines occur disproportionately among women (Sax, in press).

These findings are especially discouraging when one considers the importance of math confidence on student achievement. Mathematical self-concept has been shown to be a positive predictor of persistence in math (Sherman, 1983), performance on tests of math ability (Ethington, 1988; Marsh, Smith, & Barnes, 1985; Meece, et al., 1982; Sax, undated; Sherman, 1982), as well as scientific career aspirations and college grades (Sax, undated).

Given the unique qualities of mathematical self-concept, it is important to study its development separately from that of overall academic self-concept. However, because research on college students tends to incorporate math self-concept into a composite measure of academic self-concept (combining self-ratings of academic ability, writing ability, and math ability into a single measure), little research is available on the factors associated specifically with the development of math self-concept.

In a study that ultimately led to the questions addressed in this paper, Sax (in press) examined the factors associated with the development of math self-concept among an overall sample of college men and women. This study described a number of pre-college characteristics, college environments, and college student involvement measures that were related to gains in math confidence during college. Once students' initial confidence in math was controlled, it was found that high school grades, SAT scores, and an exposure to and interest in math and science were predictors of math self-concept development during college. Students' choice of college major was also an important predictor of math self-concept: students who majored in fields which require the use of math skills (such as math, physical science, and engineering) were more likely to gain confidence in math. Math self-concept was also influenced by aspects of the peer environment (such as the negative effects of competition), by institutional type and control, and by college activities that further reinforced students' comfort with numbers (i.e., the number of math and science courses taken, satisfaction with these courses, and tutoring other students).

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

A study of the factors predicting math self-concept must also control for gender. Because of persistent differences in math confidence at all levels of education, research should pay special attention to what factors are especially pertinent to the development of math confidence among women. An analysis controlling for gender and major differences is especially important when one considers Hyde's (1990) finding (through meta-analysis) that gender differences in math self-concept become smaller as samples become more selective. With respect to the current study, Hyde's results suggest that the gender gap in math confidence may be smaller in math/science fields than in other fields.

Objectives

Using factors that have been shown to predict academic or mathematical self-concept, this study examines major and gender differences in the development of math self-concept during college. This study attempts to move beyond previous research in three primary ways: (1) by analyzing mathematical self-concept specifically, rather than incorporating it in an overall indicator of academic self-concept, (2) by separating students with high exposure to math from all other students, and (3) by analyzing men and women within these two groups separately. Special attention will be paid to those women who have remained in math/science fields, as they comprise the small minority of women college students who have enough confidence in their mathematical skills to remain in math-intensive fields, despite persistent stereotypes of women as less able in math (Meece, et al., 1982).

Methodology

Sample

The data in this study are drawn from the Cooperative Institutional Research Program 1985 Freshman Survey and 1989 Follow-Up Survey, and incorporate information regarding enrollments, earned degrees, faculty, and curriculum. The sample includes approximately 14,000 students attending 191 coeducational four-year colleges and universities. The specific subgroups used in analyses include 1,322 men and 587 women in math/science majors[1], and 4,856 men and 7,656 women in all other majors. A "maximum contribution" limit was imposed on institutions so as to prevent any single institution from contributing more than 1% to the final sample. (See Higher Education Research Institute (1991) for a complete description of sampling and weighting procedures.)

Research Methods

This study employs the "Input-Environment-Outcome" (I-E-O) methodological framework, which examines the impact of various college environments and experiences on specific student outcomes, after controlling for students' pre-college characteristics and experiences (Astin, 1991). Implementation of this model requires that any biasing effects of

[1] Math-/science majors are drawn from fields with high levels of math exposure during college: engineering, physical science, and computer science. Biological science majors are not included in the math/science category because of the significantly fewer college math courses taken by these students (Higher Education Research Institute, 1992).

"input" characteristics, such as students' SAT-Math scores, be controlled in order to obtain a relatively unbiased measure of the effect of college environments and college experiences on specific outcomes.

First, for each of the four groups, means and crosstabulations report levels of mathematical self-concept at the point of college entry, as well as four years later. Second, math self-ratings are compared to students' actual SAT-Math scores in order to assess the relative accuracy of math self-concept across the four groups. Finally, blocked regression analyses were performed separately for each group in order to compare how a standard set of self-concept predictors behaves within each sub-sample.

Variables

The dependent variable is students' self-rating of their mathematical ability four years after college entry. Respondents were asked to rate their own mathematical ability as compared with "the average person your age" on a five-point scale: "highest 10%," "above average," "average," "below average," and "lowest 10%." Regression analyses were performed on each of the four sub-groups (men and women in math/science and non-math/science majors) in accordance with the I-E-O model, with three blocks of independent variables added to the regression equation in the temporal sequence in which they may have had an effect on students' math self-concept: (1) 9 input characteristics (including a pre-test of math self-concept), (2) 12 measures of the college environment, and (3) 9 measures of student experiences in college (See Appendix A for a complete list of variables and coding schemes).

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

The second block of variables includes measures of the college environment, such as structural characteristics of institutions (selectivity, size, type and control), as well as characteristics of the peer and faculty and environments that might serve to mediate the development of math self-concept during college. Aspects of the peer group are computed separately by institution, and include: percent women undergraduates, peer intellectual self-esteem, peer science preparation, and average math and science course taking among students at the institution. Of the three faculty-derived measures, one actually represents a dimension of the peer group: the extent to which faculty perceive competition among students at each college. The two remaining faculty measures (computed separately for each institution) are the percent of women faculty and the amount of time faculty spend teaching and advising.

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

Results and discussion

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

Changes in math self-concept over four years reveal a general decline in math confidence among students in non-math/science fields (an average decline of -.10). Among students majoring in math/science fields, men experience a slight average decline in math confidence (-.02), while women in these fields become slightly more confident in math (+.03). While such changes are not substantial, it is important to point out that, on average, the overall <u>decline</u> in math self-concept during the college years is <u>not</u> shared by women who persist in generally male-dominated math/science fields.

The trends described above indicate a high confidence in math among men and women who major in math and science, and a relatively average math confidence among students in other majors. An important issue is to what extent students' perceived math ability (self-concept) relates to their actual math ability. In other words, are students under- or over-estimating their math skills? One way to examine this is to compare students math self-concept in 1985 with their scores on the mathematical portion of the SAT (SAT-M). Among the nearly 15,000 students for whom SAT scores and survey data were available, 10 percent scored at least 670 out of 800 on the SAT-M. Among all students in this sample, 18.7 percent of men and 6.3 percent of women scored in the top 10 percent on the SAT-M. Under-estimation is defined as scoring in the top 10 percent on the SAT-M, but not rating oneself in the top 10 percent in math ability. Over-estimation is defined as rating oneself in the top 10 percent in math ability, but not scoring in the top 10 percent on the SAT-M. Such a procedure allows us to examine the accuracy of math self-concept ratings among those who are (or believe they are) high ability math students.

As Table 2 indicates, under-estimation of math abilities is least likely among men in math/science, and is most likely among women in all other majors. Under-estimation among students in non-math/science majors is striking: among those who scored in the top 10 percent on the SAT-M, a full 57.1 percent of women, and 46.8 percent of men do not consider themselves in the highest 10 percent in math ability. This finding is even more startling when one considers that these students had fairly recently received SAT score reports which included a percentile ranking of their math score among all test takers. While lower rates of under-estimation occur among math/science students (22.0 percent among men, 32.4 percent among women), these rates nevertheless reflect some hesitation among highly able math/science students to place themselves in the highest category of math ability.

For non-math/science students, rates of over-estimation of math ability are relatively low; only 11 percent of men, and 6.8 percent of women, rate their math abilities higher than their test scores would indicate. However, among math/science students, these rates are much higher (36.5 percent among men, and 33.0 percent among women). These findings suggest that approximately one-third of math/science students believe in their mathematical capabilities, even when they did not perform at the highest levels on the SAT-M. In sum, under-estimation of math ability is more likely among non-math/science students, while over-estimation is more likely among math/science students. To some extent, this suggests that the choice of major reflects students' beliefs about their math skills: those who are willing to admit their math ability, or to inflate their math confidence, will be more likely to pursue mathematically demanding fields in college.

Table 3 provides the results of regression analyses for all four groups. Although variables were entered in three separate blocks, standardized and unstandardized regression coefficients are based on equations after all variables have been controlled. The inclusion of all variables accounts for between 31 and 51 percent of the variance in math self-concept across the four groups. Before these results are discussed, it is important to point out some of the difficulty of comparing these four regression equations. Mainly, there is a substantial disparity between the size of the sub-groups—the largest being women in non-math/science fields (n=6,932), and the smallest being women in math/science fields (n=561). The problem here is that the large samples (non-math/science students) are more likely to produce "statistically significant" results, even when corresponding regression coefficients are relatively small. On the other hand, smaller samples (math/science students) may have moderately sized regression coefficients that are not considered "significant," but may nevertheless reveal important information about these students. For this reason, discussion of regression results will be limited primarily to those results which do not appear "chance" findings, and will not be concerned with comparing the statistical significance of findings across equations.

Input characteristics

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

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

While SAT-Math positively predicts math confidence among most students in the sample, SAT-Verbal scores generally predict lower 1989 math self-ratings. This does not imply that students with higher SAT-Verbal scores will have lower confidence in math (this is clearly not the case, as simple correlations between SAT-Verbal and 1989 math self-concept are positive). However, when key inputs are held constant, namely 1985 math self-concept and SAT-Math, students who score higher on the SAT-Verbal will tend to have lower confidence in math than one would expect, given their generally higher SAT-Math scores ($r_{\text{SAT-M} \times \text{SAT-V}}$ is at least .65 for all four groups). Such a finding lends support to the notion that students will compare their verbal and math abilities when making relative self-assessments (Marsh, 1986).

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

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

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

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

College environments

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

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

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

Another rather peculiar finding is that the percent of women in an institution is related to significant declines in math confidence among men in math/science fields. What this probably represents is an increase of math confidence among men who attend colleges with very few women (in this sample, primarily technical colleges and military schools). However, this finding poses an interesting question: How is men's confidence with math affected when they are surrounded by greater proportions of women?

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

College experiences

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

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

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

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

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

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

Pascarella, 1985a, 1985b). Why should activities such as working on a professor's research project or talking with faculty outside class enhance students' overall academic self-concept, but reduce many students' math self-concept? Such a question should be addressed by research which examines the dynamics of student-faculty interaction among men and women across disciplines.

Conclusions and Recommendations

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

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

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

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

The one particularly disturbing finding for women in math and science is that interacting with faculty is associated with declines in math confidence. While such a relationship holds among non-math/science students, it does not hold among men in math and science, suggesting an important difference between the experience of men and women in the sciences. Such a distinction suggests that future research must investigate how math and science faculty interact with male and female students, as well as how students perceive this interaction.

One particularly interesting finding for both men and women in math/science fields is the positive effect of institutional selectivity on math self-concept. While the effects of selectivity on self-concept and achievement are well-studied, results have often been contradictory, leaving researchers unsure as to whether it is better to be a "big fish in a small pond" or a "small fish in a big pond." The fact that attendance at a selective college tends to promote mathematical confidence among math/science students suggests that these students may benefit from their status as "big fish in a big pond."

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

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

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Table 1
Four-Year Changes in Mathematical Self-Rating
(Math/science majors: 1,322 men, 587 women; All other majors: 4,856 men, 7,656 women)

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

NOTE: Chi-square tests indicate statistically significant gender differences and major differences ($p<.001$) in all cases except for gender differences among math/science majors in 1989.

Table 2
Comparing math self-concepts with SAT-Math scores

	Math/science majors		All other majors	
	Men	Women	Men	Women
Under-estimators Percent of those scoring in top 10% on SAT-Math who do not rate themselves in top 10%	22.0 (491)	32.4 (139)	46.8 (675)	57.1 (385)
Over-estimators Percent of those not scoring in top 10% on SAT-math who rate themselves in top 10%	36.5 (832)	33.0 (448)	11.0 (4,181)	6.8 (7,271)

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

Table 3
Regression results: Predicting math self-concept
Unstandardized regression coefficients (standardized coefficients in parentheses)

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

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

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%."
SAT Math	Ranges from 200-800.
SAT Verbal	Ranges from 200-800.
1985 academic ability self-rating	Five-point scale: 1="lowest 10%," to 5="highest 10%."
Average high school grades (self-report)	Eight-point scale: 1="D," to 8="A or A+."
Mother's education	Eight-point scale: 1="grammar school or less," to 8="graduate degree."
Father's education	Eight-point scale: 1="grammar school or less," to 8="graduate degree."
Years of high school math/science	Four-item scale total representing total number of years of math, physical science, biological science, and computer science taken in high school..
Scientific orientation	Three-item factor scale (see Appendix 2 for items).
College Environments	
Selectivity	Average SAT (or ACT equivalent) of entering freshmen divided by 10.
Public university Private university equations) Public four-year college	All dichotomous: 1="no," 2="yes" (Private four-year category excluded from
Size	Undergraduate FTE.
Percent women faculty	Percent women among full-time faculty
Percent women students	Percent enrollment of women.
Peer science preparation	Peer mean: number of math/science courses taken in high school.
Peer intellectual self-esteem	Eight-item factor scale (see Appendix 2 for items).
Peer math/science	Peer mean: number of math/science courses taken in college.

Appendix A (con't.)
Variable Definitions and Coding Scheme

College Environments (con't.)	
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."
Interaction with faculty	Four-item factor scale (see Appendix 2 for items).
Academic interaction with classmates	Sum of two dichotomous variables: Discussed course content with students + Worked on a group project for a class
Worked on independent research project	Three-point scale: 1="not at all," to 3="frequently."
Received tutoring in courses	Three-point scale: 1="not at all," to 3="frequently."
Tutored another student	Three-point scale: 1="not at all," to 3="frequently."
Felt overwhelmed	Three-point scale: 1="not at all," to 3="frequently."

Appendix 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 (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."