ACADEMIC BACKGROUND AND SELF-BELIEFS AS PREDICTORS OF STUDENT GRADE PERFORMANCE IN SCIENCE, ENGINEERING AND MATHEMATICS

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ABSTRACT

In general, there are relatively low persistence rates in science, engineering, and mathematics (SEM); results from a recent national retention study found that only 35% of students who began college as SEM majors persisted to eventually graduate in an SEM discipline. The purpose of this study was to evaluate the joint contributions of academic background measures and other factors toward the explanation of overall grade performance in a science, engineering, or mathematics field of study. A sample of 658 students who began as new freshmen in SEM majors were included in this study. The findings from this study indicated that both academic background measures and other factors (such as self-beliefs) were significantly related to the grade performance of students in SEM majors.

There is considerable interest in student achievement in science, engineering, and mathematics (SEM). In general, there are relatively low persistence rates in SEM disciplines; results from a recent national retention study found that only 35% of students who began college as SEM majors persisted to eventually graduate in SEM disciplines (Smith, 1995). Further, there is particular interest in the identification of factors that are related to the persistence of women and minority students in SEM disciplines (Grandy, 1994). The percentage of bachelor's degrees in science and engineering that were awarded to women has increased 15% from 1968 to 1989 (Barber, 1995); in 1989, 40.2% of the bachelor's degrees awarded in science and engineering went to women. In addition, it has been suggested that differential participation in high school mathematics can adversely affect the participation of women students in college majors (such as science, engineering, and mathematics) that require mathematical skills (Oakes, 1990). However, it has been pointed out that research is needed to examine how student characteristics influence the subsequent achievement of students in SEM disciplines (Moore & Smith, 1987; Seymour, 1995).

Considerable research has examined student grade performance and persis-

tence in college and several academic background variables and other factors have been identified as significant predictors of achievement outcomes. For instance, admissions test scores and high school achievement have been shown to be significantly correlated with subsequent cumulative GPA (Baron & Newman, 1992) and with continued enrollment in college. Further, academic background and self-belief variables have been shown to be significant predictors of grade performance in specific general education courses (House, Keeley, & Hurst, 1996; House & Prion, 1998). Other studies have also found that several self-belief variables, such as academic self-concept and achievement expectancies, are also predictive of academic outcomes in college. Considering grade performance, specific personality characteristics and interests have been found to significantly predict cumulative GPA (Brown, 1994; Wolfe & Johnson, 1995). With regard to continued enrollment in college, students' intention to persist had the single largest total effect on persistence in a structural equation analysis of traditional new freshmen (Cabrera, Nora, & Castaneda, 1993). Similarly, self-perceptions of overall academic ability and drive to achieve were found to be significantly correlated with persistence for two years in college while expectations of graduating with honors were significantly related to persistence in college for four years (House, 1992).

Numerous studies have assessed the predictive relationship between academic background measures and other factors with grade performance in science, engineering, and mathematics courses. Considering academic background variables, several studies have investigated the efficacy of admissions test scores as predictors of course performance. For instance, Scholastic Aptitude Test (SAT) scores have been found to be significant predictors of grades in college algebra (Bridgeman, 1982) and finite mathematics (Troutman, 1978). Similarly, American College Testing (ACT) scores have been shown to be significantly correlated with student achievement in college algebra (Kohler, 1973), finite mathematics (House, 1995b), and calculus (Edge & Friedberg, 1984; Keeley, Hurst, & House, 1994). Other researchers have evaluated the relationship between admissions test scores and grade performance in college science courses. For example, several studies have found admissions test scores to be significant predictors of grades earned in college science courses (Craney & Armstrong, 1985; House, 1994; Ozsogomonyan & Loftus, 1979; Pederson, 1975). Finally, high school preparation (the number of years of high school mathematics taken) was a significant predictor of grades earned in a college chemistry course (House, 1995a).

A more limited number of studies have evaluated the predictive relationship between self-beliefs and subsequent grade performance in science, engineering, and mathematics courses. For instance, students' self-ratings of their mathematical ability, overall academic ability, and self-confidence in their intellectual ability significantly entered a multiple regression analysis of grade performance in introductory college mathematics (House, 1995b). Similarly, self-ratings of mathematical ability and overall academic ability were the only variables to significantly enter a multiple regression analysis of grade performance in introduc-

tory college chemistry (House, 1995a). Recent results indicate that students' self-ratings of their overall academic ability and mathematical ability and their expectations of graduating with honors were significantly correlated with grade performance in college calculus (House, 1995c). Two studies have indicated that students' self-concept was significantly related to final grades in a college algebra course (Wheat, Tunnell, & Munday, 1991), even after controlling for the effects of prior achievement (House, 1993). A study of students in a remedial college-level mathematics course found that students' beliefs about mathematics difficulty were significantly related to final course grades (Stage & Kloosterman, 1995). Finally, there is evidence that students' attitudes and motivation may be related to their achievement in mathematics, and that achievement is then predictive of their continued enrollment in more advanced mathematics courses (Meece, Parsons, Kaczala, Goff, & Futterman, 1982).

Gender differences in science and mathematics achievement, and differences in variables that are predictive of achievement outcomes, have been investigated. For instance, recent research has indicated that female students tended to show less interest in mathematics than male students, showed less confidence in their mathematical ability, and completed fewer mathematics courses (Shashaani, 1995). However, research on high school students suggests that students' self-confidence predicted mathematics achievement similarly for male and female students (Tartre & Fennema, 1995). Similarly, Sherman (1980) found that self-confidence in learning mathematics predicted subsequent algebra grades for both male and female students. Considering science courses, male students tend to have more favorable attitudes toward science than do female students (Weinburgh, 1995). Finally, in order to explain racial and gender differences in mathematics performance, Reyes and Stanic (1988) proposed a model that considers the effects of several variables including societal influence, school mathematics curricula, classroom processes, teacher attitudes, and student attitudes. Specific student attitudes that may be related to mathematics outcomes include students' comparisons of themselves with other students; those comparisons may then affect students' expectancies for their future success. In addition, students' confidence in their academic abilities may be associated with particular achievement behaviors, such as task persistence and enrollment in elective mathematics courses. However, Reyes and Stanic (1988) have pointed out that research is needed to test specific relationships proposed in their model of mathematics achievement.

Several studies have shown that students' self-beliefs and academic background were significant predictors of grade performance in college mathematics and science courses. However, further research is needed to evaluate the joint contributions of academic background and other factors toward the explanation of overall grade performance in SEM disciplines. In addition, a second purpose of this study was to determine if the predictive relationships between academic background, other factors, and achievement in SEM disciplines would be similar for all groups of students. This study was designed to extend the findings of previous research by evaluating the effects of academic background and other factors simultaneously.

METHOD

Students

The students included in this study were a sample of 658 students who began as new freshmen during four consecutive fall semesters and indicated an initial major in science, engineering, or mathematics during their first year of college. These majors included biology, chemistry, geology, physics, mathematics, and engineering. In this sample, there were 456 males and 202 females.

Measures

During an on-campus orientation period prior to the start of the fall semester of their freshmen year, all students were requested to complete the Cooperative Institutional Research Program Annual Freshman Survey (CIRP, 1988). On this survey, there were several items that measured student attitudes, family characteristics, and high school background. From those items, seven specific variables were constructed: achievement expectancies, academic self-concept, financial goals, social goals, desire for recognition, parental education, and high school curriculum. The specific items that comprised these variables are shown below. In addition, data were collected for two academic background measures (ACT Composite score and high school class percentile rank). Finally, the dependent measure examined in this study was students' cumulative GPA after one year as a major in a science, engineering, or mathematics discipline.

Variable Definitions

Parental Education	Sum of mother's and father's education (six levels each from 'grammar school or less' to 'post-graduate degree').
High School Curriculum	Sum of high school units taken in six fields: English, Physical Sciences, Mathematics, Biological Sciences, History/American Government, and Foreign Languages.
Financial Goals	Sum of student's ratings of the importance of becoming an expert in finance and commerce, being very well off financially, and being successful in own business.
Social Goals	Sum of student's ratings of the importance of promoting racial understanding, helping others in difficulty, influencing social values, influencing the political structure, taking part in community action, and promoting environmental cleanup.

Academic Self-Concept	Sum of student's self-ratings of overall academic ability, drive to achieve, mathematical ability, writing ability, and self-confidence in intellectual ability.
Achievement Expectancies	Sum of student's self-ratings of the probability of graduating with honors, making at least a B average, get bachelor's degree, and transformed ratings of expectations of failing one or more courses in college, needing extra time to graduate, and getting tutoring assistance.
Desire for Recognition	Sum of student's ratings of the importance of becoming an authority in my field and obtaining recognition from my colleagues for contributions in my special field.

Procedure

Several procedures were used to analyze the data from this study. First, correlation coefficients were computed to examine the relationships between each of the predictor variables. Correlation coefficients were then computed to investigate the relationships between each of the predictor variables and subsequent grade performance. Correlations were computed for the entire sample and separately for male and female students. Ordinary least-squares multiple regression procedures were used to investigate the relative contribution of each predictor variable toward the explanation of cumulative grade performance after one year as a major in a science, engineering, or mathematics field of study. Multiple regression analyses were done using only self-beliefs as predictors and then using the entire set of self-beliefs and academic background measures as predictors. These multiple regression analyses were done for the entire sample and separately for male and female students.

RESULTS

Correlations between each of the predictor variables for the entire sample are shown in Table 1. Several significant correlations were obtained. For instance, ACT Composite scores were significantly positively correlated with achievement expectancies, academic self-concept, parental education, and high school curriculum; in each case, students with higher ACT Composite scores tended to show higher levels on each self-belief measure. Interestingly, ACT Composite scores were significantly negatively correlated with financial goals and social goals; students with lower ACT scores tended to have higher financial goals and social goals. High school class percentile rank was significantly correlated with ACT Composite score, academic self-concept, and achievement expectancies; students with higher class ranks tended to have higher achievement expectancies, higher academic self-concept, and higher ACT scores. Finally, there was a

significant negative correlation between high school class percentile rank and financial goals; students with lower class ranks tended to have higher financial goals.

Correlations between each predictor variable and first-year grades in SEM disciplines are presented in Table 2. Considering the entire sample, several variables were significantly correlated with grade performance; significant positive correlations were seen for several variables (academic self-concept, achievement expectancies, ACT Composite score, and high school class percentile rank). There was also a significant negative correlation between financial goals and first-year GPA. The same significant relationships were also seen for male students. Considering female students, three variables (academic self-concept, ACT Composite score, and high school class percentile rank) showed significant positive correlations with first-year GPA. In addition, there was a significant negative correlation between financial goals and first-year GPA for female students.

Findings from the multiple regression analyses of the first-year grades of SEM majors (excluding academic background measures as predictors) are summarized in Table 3. Considering the entire sample, one self-belief variable (academic self-concept) and one other factor (financial goals) significantly entered the regression equation. In this instance, students with higher academic self-concept tended to earn higher grades while students with higher financial goals tended to earn lower grades. This finding is probably due to the fact that students with higher financial goals tended to have lower level of academic preparation (as measured by ACT Composite scores and high school class percentile ranks). The overall regression equation for the entire sample was significant ($F(7,650) = 12.50$, $p = .0001$) and explained 12.0% of the variance in the grades of SEM majors. When analyzed by student gender, the same two variables (academic self-concept and financial goals) significantly entered the regression equation for male students. As was the case for the entire sample, male students with higher academic self-concept tended to earn higher grades while students with higher financial goals tended to earn lower grades. In addition, the overall regression equation for male students was significant ($F(7,448) = 9.25$, $p = .0001$) and explained 13% of the variance in first-year grades by SEM majors. Considering female students, the same two variables (academic self-concept and financial goals) significantly entered the multiple regression equation. Further, the overall regression equation for female students was significant ($F(7,194) = 3.57$, $p = .0012$) and explained 11% of the variance in first-year grades.

Results from the multiple regression analyses of first-year grades of SEM majors using the entire set of predictor variables (both academic background measures and other factors) for the entire sample and by student gender are shown in Table 4. Considering the entire sample, the two academic background measures were the two most significant predictor variables in the equation; high school class percentile rank entered the regression equation first as the most significant predictor while ACT Composite score entered the equation second and was also significant. In addition, two other variables (financial goals and academic self-concept) significantly entered the regression equation. As was the

case before, students with higher academic self-concept tended to earn higher first-year grades while students with higher financial goals tended to earn lower grades. The overall regression equation was significant ($F(9,649) = 29.97$, $p = .0001$) and explained 29% of the variance in the first-year grades of SEM majors. When analyzed by student gender, four variables significantly entered the regression equation for male students. High school class percentile rank entered the regression equation first as the most significant predictor while ACT Composite score entered the equation second and was also significant. Two other variables (financial goals and academic self-concept) were also significant predictors in the multiple regression equation. Finally, the overall regression equation for male students was significant ($F(9,446) = 21.00$, $p = .0001$) and explained 30% of the variance in first-year grades. Considering female students, both academic background measures significantly entered the multiple regression equation. In contrast to the findings for male students, ACT Composite score entered the regression equation first as the most significant predictor for female students. One additional variable (achievement expectancies) also significantly entered the regression equation for female students. In this instance, female students with higher achievement expectancies tended to earn higher first-year grades. Finally, the overall regression equation for female students using the entire set of predictor variables was significant ($F(9,192) = 10.46$, $p = .0001$) and explained 33% of the variance in first-year grades.

DISCUSSION

The findings from this study identify several characteristics that are predictive of student grade performance in science, engineering, and mathematics. First, both academic background measures were significant predictors of grade performance for the entire sample and for male and female students. Second, the results of this study indicate that several other factors were significantly related to the grade performance of students in SEM majors. These results also indicate that the combination of academic background measures and other factors predicted subsequent grade performance similarly for male and female students. These results provide support for parts of the Reyes and Stanic (1988) model of mathematics achievement; specifically, student self-beliefs were related to achievement outcomes in science, engineering, and mathematics.

These were several limitations to the present study. First, students from only one institution were included in this analysis. Further research on students at other types of institutions are needed to assess the generalizability of these findings. Previous multi-institution studies have been conducted to evaluate the predictive validity of admissions tests (Rubin, 1980; Zwick, 1993). A smaller number of multi-institution studies have evaluated the utility of other factors as predictors of undergraduate student achievement; in most instances, those studies have evaluated college attrition as the criterion measure (Ethington, 1990; Pavel & Padilla, 1993). Consequently, further research is needed to continue to assess the efficacy of academic background measures and other factors as pre-

dictors of student achievement in SEM majors.

These results provide several directions for future research. For instance, Astin (1995) has developed an assessment model that includes a consideration of student input (characteristics that the student brings to college), the effects of the college environment, and measures of educational outcomes. This study has focused on the input and outcomes part of the assessment model. Further research is needed to evaluate the effects of specific environmental variables as mediators of those input-outcome relationships. For instance, previous research has shown that an environmental factor (such as tutoring program participation) results in improved grade performance and persistence by college students (House & Wohlt, 1990, 1991) and those improved outcomes from tutoring can vary as a function of student characteristics (House & Wohlt, 1989, 1992). Consequently, additional study is needed to identify specific environmental variables that impact the college experiences of SEM majors. However, these results provide an initial understanding of several factors that are related to the first-year grade performance of students majoring in science, engineering, or mathematics.

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TABLE 1. INTERCORRELATIONS BETWEEN PREDICTOR VARIABLES (ALL STUDENTS)

Predictor Variables	2	3	4	5	6	7	8	9
1. Achievement Expectancies	.12**	.03	.10**	.17**	.46**	.05	.22**	.26**
2. High School Curriculum	---	-.07	.08*	.05	.12**	.16**	.16**	.07
3. Financial Goals		---	.29**	.35**	.09*	-.06	-.20**	-.18**
4. Social Goals			---	.36**	.16**	-.04	-.13**	.01
5. Desire for Recognition				---	.24**	.00	-.07	-.03
6. Academic Self-Concept					---	.03	.28**	.30**
7. Parental Education						---	.13**	-.07
8. ACT Composite Score							---	.23**
9. High School Class Percentile Rank								---

**p < .01
*p < .05

TABLE 2. CORRELATIONS BETWEEN PREDICTOR VARIABLES AND FIRST-YEAR GRADES IN SCIENCE, ENGINEERING, AND MATHEMATICS

Predictor Variables	All Students	Males	Females
Achievement Expectancies	.166**	.187**	.095
High School Curriculum	.070	.052	.081
Financial Goals	-.204**	-.195**	-.169*
Social Goals	-.005	.002	-.096
Desire for Recognition	-.036	-.052	-.005
Academic Self-Concept	.248**	.257**	.250**
Parental Education	.011	-.001	.016
ACT Composite Score	.324**	.290**	.479**
High School Class Percentile Rank	.481**	.488**	.431**

**p < .01
*p < .05

TABLE 3. SUMMARY OF STEPWISE MULTIPLE REGRESSION ANALYSIS OF FIRST-YEAR GRADES IN SCIENCE, ENGINEERING AND MATHEMATICS (EXCLUDING ACADEMIC BACKGROUND VARIABLES

Step	Variable Entered	Model R-Square	*F*
All Students			
1	Academic Self-Concept	.06	42.82**
2	Financial Goals	.11	38.88**
3	Achievement Expectancies	.12	2.12
4	Desire for Recognition	.12	0.51
5	Social Goals	.12	0.49
6	High School Curriculum	.12	0.22
7	Parental Education	.12	0.17
Male Students			
1	Academic Self-Concept	.07	32.09**
2	Financial Goals	.11	24.51**
3	Achievement Expectancies	.12	3.54
4	Desire for Recognition	.12	1.29
5	Social Goals	.12	0.80
6	Parental Education	.13	0.65
7	High School Curriculum	.13	0.04
Female Students			
1	Academic Self-Concept	.06	13.28**
2	Financial Goals	.10	8.25**
3	High School Curriculum	.11	1.26
4	Social Goals	.11	1.33
5	Achievement Expectancies	.11	0.51
6	Desire for Recognition	.11	0.08
7	Parental Education	.11	0.02

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

TABLE 4. SUMMARY OF STEPWISE MULTIPLE REGRESSION ANALYSIS OF FIRST-YEAR GRADES IN SCIENCE, ENGINEERING, AND MATHEMATICS

Step	Variable Entered	Model R-Square	*F*
All Students			
1	High School Class Percentile Rank	.23	197.86**
2	ACT Composite Score	.28	43.11**
3	Financial Goals	.29	6.52*
4	Academic Self-Concept	.29	5.49*
5	Social Goals	.29	1.21
6	Achievement Expectancies	.29	0.26
7	High School Curriculum	.29	0.05
8	Parental Education	.29	0.05
9	Desire for Recognigion	.29	0.00
Male Students			
1	High School Class Percentile Rank	.24	142.23**
2	ACT Composite Score	.27	19.52**
3	Financial Goals	.28	6.31*
4	Academic Self-Concept	.29	7.58**
5	Social Goals	.30	2.40
6	High School Curriculum	.30	0.54
7	Achievement Expectancies	.30	0.27
8	Desire for Recognition	.30	0.22
9	Parental Education	.30	0.21
Female Students			
1	ACT Composite Score	.23	59.56**
2	High School Class Percentile Rank	.30	21.22**
3	Achievement Expectancies	.32	4.00*
4	Academic Self-Concept	.32	1.12
5	Social Goals	.32	1.05
6	Parental Education	.33	0.75
7	High School Curriculum	.33	0.41
8	Desire for Recognition	.33	0.02
9	Financial Goals	.33	0.01

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