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ABSTRACT

In order to avoid the projected shortfall of a half a million science and engineering professionals by the year 2010, many believe that we must find ways to increase the number of minorities and women who choose the sciences as a discipline of study. This study, involving 500 high school students, explores the collective relationships among science self-efficacy, attitudes toward science, and the attributions for success and failure in science. Student attitude toward science was measured using the Test of Science Related Attitudes (TOSRA). The Science Self-Efficacy Questionnaire was developed to measure beliefs about competence in school science tasks. In predicting physics, biology, and chemistry self-efficacy, the biographical and aptitude blocks together explained significant variation. In predicting laboratory self-efficacy, the combination of biographical and aptitude measures explained significant but modest variance. The researchers concluded that certain stable variables (aptitude) predict science self-efficacy. However, alterable variables (attributions and attitudes) explained substantially more variation in science self-efficacy, and the overall effect sizes were very large. Contains 28 references. (ZWH)

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Explaining Science Self-efficacy[1]

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Why is Science Unattractive?

Fewer students than ever are electing science as a course of study or a profession (Bell, 1989; Ware & Lee, 1988). In the face of the National Science Foundation's projections of a shortfall of a half a million science and engineering professionals by the year 2010 (Rawls, 1991), the American Chemical Society advocates recruitment of more females and minorities. Unfortunately, these two populations have a long history of underrepresentation in the sciences (Cooper, 1983; Hill, Pettus & Hedin, 1990; Levine, 1985).

Social cognitive theory predicts that if attitudes toward science, attributions about science success, and, especially, science self-efficacy can be improved, females and minorities might be more attracted to science as a profession. The purpose of this research was to explore the relationships among science self-efficacy, attitudes toward science, and the attributions for success and failure in science. Earlier research has examined these constructs separately; we studied them collectively.

It has be argued that chronic underrepresentation of women and minorities in professional occupations results partly from negative attitudes and from low self-efficacy beliefs (Betz & Hackett, 1981; Lent, Brown, and Larkin, 1986; Post, Stewart, and Smith, 1991). Attitudes toward science are dependably correlated with course selection and career choice in science (Hill et al., 1990). The more specific construct of self-efficacy refers to a person's belief that he or she can accomplish a particular behavior. The aspects of self-efficacy relevant to our work deal with science tasks in chemistry, biology, physics, and laboratory work. Efficacy expectations are claimed to have causal influence on the choice of approaching or avoiding the behaviors, as well as how much effort will be expended (Bandura, 1993). Many researchers (cf. Hackett, 1985; Lent, Lopez & Bieschke, 1991; Meece, Wigfield & Eccles, 1990; Randhawa, Beamer & Lundberg, 1993) have found evidence of linkages between self-efficacy beliefs and performance behaviors. In our study, we move back one step and ask how various antecedent variables relate to science self- efficacy.

Science Self-Efficacy

Several researchers found that females had greater self- efficacy about completion of educational requirements and job duties for stereotyped "female occupations" (e.g. teacher,

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secretary, dental hygienist) (Betz & Hackett, 1981; Post-Kammer & Smith, 1986). Lent et al. (1986) found that self-efficacy contributed significantly to the prediction of science and engineering grades, persistence and range of career options, even when the variance due to ability, high school achievement, and vocational interest had been removed. In an earlier study, Lent, Brown & Larkin (1984) showed that self-efficacy scores moderately correlated with math PSAT scores and high school rank. They also found no gender differences in terms of perceived ability among their students, who were all aspiring science majors.

Hackett (1985) used path analysis to describe the relationship between mathematics self-efficacy and the choice of math-related college majors. She found that gender-related socialization and the amount of math preparation (i.e., years of high school math) influenced the level of math achievement (measured by math ACT scores), which in turn influenced math self- efficacy. Math self-efficacy was then predictive of both math anxiety and math-related major choices.

The findings of Meece et al. (1990) were consistent with previous research: math self-efficacy predicted math anxiety and students' perceptions of their math ability mediated the effects of past performance. Self-efficacy influenced the perceived importance of mathematics, which in turn, predicted course enrollment intentions. Math anxiety did not show a direct influence on course enrollment intentions or on subsequent math grades, but rather the effects of anxiety are indirect.

Lent, Lopez and Bieschke (1991) explored the presumed antecedents of math self-efficacy as well as the relationships of these beliefs to outcome expectations, interest in math-related college courses, and science-based careers. Their findings tended to confirm Bandura's (1986) hypothesis that personal performance accomplishments were the greatest source of efficacy information. Although they found (again consistent with prior research) that men exhibited higher math self-efficacy and math ACT scores, this difference was small and could possibly be attributed to differential experience with math courses. Finally, their data supported the notion that self-efficacy mediates the effect of prior performance on interest, with interest mediating the effect of self-efficacy on career choices.

Literature about differential science self-efficacy among ethnic groups is nearly nonexistent. Post, Stewart & Smith (1991) did examine the relationship of self-efficacy to consideration of math/science careers among black freshmen. They reported that black males had greater self-efficacy than black females with respect to considering a career in science.

Attributions for Science Behaviors

From a different aspect of social cognition, DeBoer (1984) used the framework of attribution theory to investigate the factors explaining students' decisions to continue in science following their first college science course. Gender, mathematical aptitude (SAT-Math) and performance were unrelated to the decision to continue in science. But for successful students, the intention to continue in science was related to their attribution to ability and to task difficulty. For unsuccessful students, only the attribution to task difficulty approached significance. In a subsequent study, DeBoer (1987) analyzed a path model relating cognitive motivational constructs and students' intentions to continue in college chemistry. He found no

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gender differences among the students enrolled in the introductory chemistry course. The intention to take more chemistry was directly related to students' expectations for success, which was influenced by their self-perceived ability and perceived effort.

Gender differences have been found in attributions for success and failure among students from elementary grades through high school (Ryckman and Peckman, 1987). In math and science coursework, females more often ascribed their successes to effort, whereas males typically preferred ability as an explanation.

Attitudes Toward Science

Attitude toward science has been shown to correlate with achievement (Napier & Riley, 1985), to influence the selection of science courses, and to affect the choice of science as a career (Germann, 1988; Hill, Pettus & Heiden, 1990; Yager & Bonsetter, 1984). Schibeci & Riley (1986) proposed a causal model to explain the relationship between students' background, perceptions, attitudes and achievement. They found that gender influenced attitudes and achievement, with females scoring lower on both. Hill et al. (1990) found a lack of interest in science careers and lack of participation in science-related activities, outside of school, on the part of middle and high school girls. Ware & Lee (1988), examining a nationally representative sample of high ability college students, found that the women perceived a career in science as incompatible with their futures.

Methods

Subjects

A four-part survey was administered to a nationwide sample of about 500 high school students during the 1992-1993 academic year. The sample was stratified to assure representativeness in SES, geographical region, and community type (urban, suburban, rural). One part of the survey consisted of biographical data (e.g., sex, ethnic group). The remainder of the survey contained outcome measures: attitudes toward science, attributions for success and failure in science, and science self-efficacy. In addition, school personnel supplied PSAT scores, GPA, and high school rank for each of the students. Missing data were scattered throughout the data set; this reduced the usable number of cases to 233.

Measures

Attitudes toward science was measured by Fraser's (1981) well-researched Test of Science-Related Attitudes (TOSRA). A 16- item Science Attribution Scale was developed based on Weiner's (1985) theory and pilot tested with 182 New England high school students. An exploratory principal factor analysis extracted four factors, explaining 80% of the item covariation. The factors showed satisfactory internal consistency estimates: Luck (4 items, $\alpha = .85$); Ability (5 items, $\alpha =. 68$); Lack of effort (2 items, $\alpha = .78$); and Task ease (2 items, $\alpha = .64$).

The Science Self-Efficacy Questionnaire was developed to measure beliefs about competence in school science tasks. To estimate the reliability and the dimensionality of this instrument, a pilot test was conducted among 826 high school students in New England in June

1992. Four dimensions were developed from an exploratory principal factor analysis; they explained 89% of the common variance. Cronbach's alpha estimates for the four scale scores were satisfactory: Biology Self-Efficacy (8 items, / = .87); Physics Self-Efficacy (5 items, / = .93); Chemistry Self-Efficacy (7 items, / = .85); and Laboratory Self- Efficacy (6 items, / = .90). More details about this instrument's development and psychometric properties are given in Smist (1992).

Analyses

The analytic model followed Bandura's (1986) self-efficacy theory, in which he asserts that biographical characteristics (including aptitude) influence attributions, which in turn influence self-efficacy. Self-efficacy's influence on behavior, which is already well documented, was not studied in this project. To explain variation in science self-efficacy, four hierarchical regressions were arranged, one for each of the Science Self- Efficacy subscores. In each regression, an initial block of biographical variables—student sex, age, and race—was entered. Race was effect coded for two categories: white and nonwhite. Next, a block of aptitude measures was forced into the equation. These measures were PSAT scores (composite of verbal plus math), GPA, and high school class percentile rank. Finally, a block of self-reported perceptual measures entered the regression. This block consisted of six TOSRA (science attitude) scores, plus four scores from the Science Attribution Scale.

Results and Discussion

Data Screening

The data were examined for multivariate outliers. A case was declared an outlier if it's Mahalanobis D^2 value was significantly different ($p < .0002$) from the centroid of all data. Five such cases were located and deleted from further analysis. Table 1 gives means and standard deviations for all variables. It can be seen that students showed the strongest self-efficacy for lab activities ($M = 4.01$ on a 5-point scale), and lowest on physics self-efficacy ($M = 3.56$).

Main Analyses

In predicting Physics Self-Efficacy, the biographical and aptitude blocks together explained significant variation (adjusted $R^2 = .19$). The last block, perceptual measures, showed a sizable increase in explained variance (to cumulative adjusted $R^2 = .32$, increment F [10,211] = 5.26, $p < .0001$). Table 2 summarizes this regression. It can be seen that the TOSRA measures were the strongest variables explaining variation in physics self-efficacy.

In predicting Biology Self-Efficacy, the biographical and aptitude blocks together explained significant variation (adjusted $R^2 = .08$). The final block of perceptual measures gave a significant increase in explained variance (cumulative adjusted $R^2 = .41$, increment *F* [10,211] = 9.44, $p < .0001$). In Table 3, it can be seen that only one TOSRA subscore was important, and two attribution scores—perceived luck and perceived ability—were significant in explaining variation in biology self-efficacy.

For Chemistry Self-Efficacy, the combination of biographical and aptitude measures explained significant variation (adjusted $R^2 = .11$). As before, the block of perceptual measures significantly augmented the explained variance (cumulative adjusted R^2 = .38, increment F [10,211] = 10.47, p < .0001). Table 4 summarizes this regression. As in the prediction of Biology Self-Efficacy, only a single TOSRA measure was significant, whereas two attribution scores (luck and ability) were important contributors to the explanation of variation in chemistry self-efficacy.

Finally, in predicting Laboratory Self-Efficacy, the combination of biographical and aptitude measures explained significant but modest variation (adjusted R^2 = .12). Once again, the block of perceptual measures significantly increased the explained variance (cumulative adjusted R^2 = .31, increment F [10,211] = 7.17, p < .0001). Table 5 summarizes this regression. Unlike previous regressions, all aptitude measures contributed significantly, two TOSRA scores were important, but no attribution measure helped to explain variation in laboratory self-efficacy.

In summary, the regressions showed the biographical variables to be fairly weak predictors of science self-efficacy (adjusted R^2 = .00 to .04). The set of aptitude variables was somewhat stronger (increment in adjusted R^2 = .08 to .17). The perceptual variables, as a group, were considerably better at explaining science self-efficacy. Their incremental validities (adjusted R^2 ranged from .13 to .33). The overall adjusted R^2s ranged from .31 (Laboratory) to .38 (Chemistry). These effect sizes are somewhat higher than Cohen's (1988) category termed "large."

Bandura (1993) has argued that robust self-efficacy is essential in helping to steer a person through challenging activities and environments. It makes sense, then, to improve the science self-efficacy of prospective students; strong self- efficacy makes it more likely that they will approach rather than avoid work in science. We found, as hypothesized, that certain stable variables (aptitude) predict science self-efficacy. However, alterable variables (attributions and attitudes) explained substantially more variation in science self-efficacy, and the overall effect sizes were very large. It may be, then, that Bandura's (1986) list of alterable influences on self- efficacy should be expanded to include attributions and attitudes. Of course, this was a correlational study from which no causal inference may be drawn. It will be useful to investigate whether experimental manipulation of attributions (cf. Schunk & Rice, 1986) and attitudes will actually enhance self-efficacy, especially in ethnic subgroups showing weak confidence in their skills.

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Table 1
Means and Standard Deviations for All Variables

Variable	M	SD
(Biographical)		
Sex	1.55	0.50
Race	0.64	0.36
Age	16.82	0.81
(Aptitude)		
HS %ile Rank	0.23	0.21
PSAT Total	99.21	24.21
GPA	3.37	0.59
(Perceptual)		
Tosra 1	3.18	0.66
Tosra 2	3.85	0.55
Tosra 3	2.24	0.52
Tosra 4	3.61	0.53
Tosra 5	2.25	0.80
Tosra 6	2.18	0.45
Luck	2.42	0.93
Ability	2.63	0.88
Effort	3.71	1.12
Task Ease	3.35	1.14
(Criteria)		
Physics Self-Efficacy	3.56	0.86
Biology Self-Efficacy	3.75	0.77
Chemistry Self-Efficacy	3.69	0.83
Lab Self-Efficacy	4.01	0.70

TOSRA 1 - Attitude toward science/career & leisure enjoyment
TOSRA 2 - Preference for experimentation
TOSRA 3 - Social importance of science
TOSRA 4 - Normality of scientists
TOSRA 5 - Attitude toward science classes
TOSRA 6 - Openness to new ideas

Table 2
Summary of Hierarchical Regression at Last Step Predicting Physics Self-Efficacy

Predictor	R	Increase in Adjusted R^2	Cumulative Adjusted R^2	F	p
(Biographical)	.19	.02	.02	2.91	.04
Sex					
Race*					
Age					
(Aptitude)	.46	.17	.19	13.29	<.01
HS %ile Rank					
PSAT Total*					
GPA					
(Perceptual)	.61	.13	.32	5.26	<.01
Tosra 1					
Tosra 2*					
Tosra 3					
Tosra 4*					
Tosra 5					
Tosra 6*					
Luck					
Ability					
Effort					
Task Ease					

*$p < .05$.

TOSRA 1 - Attitude toward science/career & leisure enjoyment
TOSRA 2 - Preference for experimentation
TOSRA 3 - Social importance of science
TOSRA 4 - Normality of scientists
TOSRA 5 - Attitude toward science classes
TOSRA 6 - Openness to new ideas

Table 3
Summary of Hierarchical Regressions at Last Step Predicting Biology Self-Efficacy

Predictor	R	Increase in Adjusted R^2	Cumulative Adjusted R^2	F	p
(Biographical)	.03	.00	.00	0.37	.77
Sex					
Race*					
Age					
(Aptitude)	.32	.08	.08	2.47	.06
HS %ile Rank					
PSAT Total*					
GPA					
(Perceptual)	.62	.33	.41	9.44	<.01
Tosra 1					
Tosra 2*					
Tosra 3					
Tosra 4*					
Tosra 5					
Tosra 6*					
Luck					
Ability					
Effort					
Task Ease					

* $p < .05$.

TOSRA 1 - Attitude toward science/career & leisure enjoyment
TOSRA 2 - Preference for experimentation
TOSRA 3 - Social importance of science
TOSRA 4 - Normality of scientists
TOSRA 5 - Attitude toward science classes
TOSRA 6 - Openness to new ideas

Table 4
Summary of Hierarchical Regressions at Last Step Predicting Chemistry Self-Efficacy

Predictor	R	Increase in Adjusted R^2	Cumulative Adjusted R^2	F	p
(Biographical).	.18	.02	.02	2.11	.10
Sex					
Race*					
Age					
(Aptitude)	.37	.09	.11	2.52	.06
HS %ile Rank					
PSAT Total*					
GPA					
(Perceptual)	.65	.26	.37	10.47	<.01
Tosra 1					
Tosra 2*					
Tosra 3					
Tosra 4*					
Tosra 5					
Tosra 6*					
Luck					
Ability					
Effort					
Task Ease					

* $p < .05$.
Note. Because of rounding error, cumulative adjusted R^2 does not quite match increase in adjusted R^2.

TOSRA 1 - Attitude toward science/career & leisure enjoyment
TOSRA 2 - Preference for experimentation
TOSRA 3 - Social importance of science
TOSRA 4 - Normality of scientists
TOSRA 5 - Attitude toward science classes
TOSRA 6 - Openness to new ideas

Table 5
Summary of Hierarchical Regressions at Last Step Predicting Laboratory Self-Efficacy

Predictor	R	Increase in Adjusted R^2	Cumulative Adjusted R^2	F	p
(Biographical)	.23	.04	.04	3.69	.01
Sex					
Race*					
Age					
(Aptitude)	.38	.08	.12	3.38	.02
HS %ile Rank					
PSAT Total*					
GPA					
(Perceptual)	.60	.19	.31	7.17	<.01
Tosra 1					
Tosra 2*					
Tosra 3					
Tosra 4*					
Tosra 5					
Tosra 6*					
Luck					
Ability					
Effort					
Task Ease					

* $p < .05$.

TOSRA 1 - Attitude toward science/career & leisure enjoyment
TOSRA 2 - Preference for experimentation
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TOSRA 4 - Normality of scientists
TOSRA 5 - Attitude toward science classes
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