Sources of Science Self-Efficacy Beliefs of Middle School Students

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Abstract: The purpose of this study was to investigate the degree to which A. Bandura's (1997) hypothesized sources of self-efficacy predict the science self-efficacy beliefs of middle school students ($N = 319$), to replicate previous findings that science self-efficacy predicts science achievement, and to explore how science self-efficacy and its antecedents differ by gender. Significant correlations were found between mastery experiences, vicarious experiences, social persuasions, physiological arousal, and self-efficacy. Only mastery experiences significantly predicted science self-efficacy. Girls reported stronger science self-efficacy than did boys. Findings support and extend the theoretical tenets of Bandura's social cognitive theory. © 2006 Wiley Periodicals, Inc. J Res Sci Teach 43: 485–499, 2006

The purpose of this study was to investigate the degree to which Bandura's (1997) hypothesized sources of self-efficacy predict the science self-efficacy beliefs of middle school students. Self-efficacy has been found to be a strong predictor of academic achievement, course selection, and career decisions across domains and levels. Information about the antecedents of self-efficacy may help science educators facilitate student progress in science during the middle school years and into high school.

Although virtually all students take at least 1 year of science in high school, the number who take additional science courses is considerably lower. Only 60% of students take 2 years of high school science and the percentage drops to 25% who take 3 years of science (National Center for Educational Statistics [NCES], 2002). Even fewer students take advanced science courses: 16% take Advanced Placement (AP) biology, 6% AP chemistry, and 4% AP physics.

Seeking to increase science course-taking and achievement, science educators have examined a wide range of factors that influence academic choices and performance. One potentially powerful influence is the confidence with which students approach science (Andre,

Whigham, Hendrickson, & Chambers, 1999; Britner & Pajares, 2001; Kupermintz, 2002; Lau & Roeser, 2002). Self-efficacy researchers posit that students' belief in their ability to succeed in science tasks, courses, or activities, or their *science self-efficacy*, influences their choices of science-related activities, the effort they expend on those activities, the perseverance they show when encountering difficulties, and the ultimate success they experience in science (Bandura, 1997; Britner & Pajares, 2001; Zeldin & Pajares, 2000). This makes self-efficacy a prime focus for science educators who want to increase student accomplishment and engagement in science.

Bandura (1986) contended that students' self-efficacy beliefs are often better predictors of the academic successes they attain than are objective assessments of their abilities. This is because these beliefs mediate the effects of prior achievement, knowledge, and skills on subsequent achievement (Schunk, 1985). Motivation researchers have established that students' self-efficacy in their academic capabilities is related to academic motivation and performance outcomes in domains that include science, mathematics, and language arts (Britner & Pajares, 2001; Lent, Brown, & Gore, 1997; Pajares & Valiante, 1999; Shell, Colvin, & Bruning, 1995; and see Pajares, 1997, for an overview of findings related to self-efficacy beliefs in the context of schooling). Self-efficacy beliefs are also positively associated with key motivation constructs such as self-regulation (Zimmerman, 2000; Zimmerman & Bandura, 1994), mastery goal orientation (Urdan, 1997), adaptive causal attributions (Stajkovic & Sommer, 2000), and self-concept (Bong & Skaalvik, 2003).

Self-efficacy beliefs affect academic performance by influencing a number of behavioral and psychological processes (Bandura, 1986, 1997). In science, students who have a strong belief that they can succeed in science tasks and activities will be more likely to select such tasks and activities, work hard to complete them successfully, persevere in the face of difficulty, and be guided by physiological indexes that promote confidence as they meet obstacles. Alternatively, students who do not believe that they can succeed in science-related activities will avoid them if they can, and will put forth minimal effort if they cannot. When confronted with the typical challenges that science involves, they will be more likely to give up and to experience the stresses and anxieties that help ensure the erosion of their efforts.

Previous research has established that science self-efficacy is associated with science achievement and science-related choices across grade levels. At the college level, science self-efficacy predicts achievement (Andrew, 1998) and persistence in science-related majors and career choices (Gwilliam & Betz, 2001; Lent, Brown, & Larkin, 1984; Luzzo, Hasper, Albert, Bibby, & Martinelli, 1999). In high school students, science self-efficacy correlates with science achievement and is a better predictor of achievement and engagement with science-related activities in and out of the classroom than are gender, ethnicity, and parental background (Kupermintz, 2002; Lau & Roeser, 2002). Among middle school students (Britner & Pajares, 2001; Pajares, Britner, & Valiante, 2000), science self-efficacy predicts science achievement, with girls and White students having higher science grades and stronger self-efficacy than do boys or African American students.

Given the demonstrated influence of self-efficacy on achievement in academic domains such as science, researchers have turned to an examination of the sources of self-efficacy. Bandura (1986, 1997) theorized that students form their self-efficacy beliefs by interpreting information from four sources. The most influential is the interpretation of previous performance, or *mastery experience*. Students engage in tasks and activities, interpret the results of their actions, use these interpretations to develop beliefs about their capability to engage in subsequent tasks or activities, and act in concert with the beliefs created. Experiences interpreted as successful generally raise confidence; experiences interpreted as unsuccessful generally lower it. Successes that occur as a result of overcoming challenges may promote a more resilient sense of self-efficacy than those

successes that are easily won. But successful mastery experiences alone do not determine self-efficacy. Rather, individuals must cognitively process these experiences along with personal and environmental factors that include previously held self-beliefs, the perceived difficulty of the task, effort expended in the task, and help received in the completion of the task.

Students also form their self-efficacy beliefs through the *vicarious experience* of observing others perform tasks. They use this information to evaluate their own likelihood of success at the same or similar tasks. This source of information is weaker than mastery experience in helping create self-efficacy beliefs, but when students are uncertain about their own abilities or when they have limited prior experience they become more sensitive to it. Models perceived to possess characteristics similar to the observer are the most effective in increasing self-efficacy in the observer. A significant model in a student's life can help instill self-beliefs that will influence the course and direction that his or her life will take.

Social persuasion, which includes exposure to the verbal and nonverbal judgments that others provide, is also an important source of information. Effective persuaders must cultivate students' beliefs in their capabilities while at the same time ensuring that the envisioned success is attainable. Also, just as positive persuasions may work to encourage and empower, negative persuasions can work to defeat and weaken self-efficacy beliefs. In fact, it is usually easier to weaken self-efficacy beliefs through negative appraisals than to strengthen such beliefs through positive encouragement. Feedback that provides suggestions for improvement and emphasizes improvement in performance rather than how far one still has to improve has a greater facilitative effect on self-efficacy. Social persuasion alone does not produce a positive sense of self-efficacy, but rather operates in concert with other sources of self-efficacy to affect self-confidence.

Finally, *physiological states* such as anxiety, stress, arousal, and mood states also provide information about efficacy beliefs. Students gauge their degree of confidence by the emotional state they experience as they contemplate or engage in an action. People more readily expect success when they experience positive arousal than when they suffer high anxiety, tension, and stress associated with a particular activity or domain. Negative physical states, or those interpreted as negative, may inhibit performance and increase the likelihood of a poor outcome, thus contributing to lower self-efficacy. Individuals also vary in the degree to which they focus on internal states and in the degree to which they are inclined to associate positive or negative outcomes with such states. The existing degree of self-efficacy, the complexity of the task at hand, and previous experiences in similar situations also affect the interpretation of physiological and affective states and the contribution they make to self-efficacy. As with the previous sources, it is the interpretation of physiological states that contributes to self-efficacy.

Thus, students construct their self-efficacy beliefs through the interpretation and integration of information from these four sources. The strength of the contribution made by each source varies depending on the domain in question and on the cognitive processing strategies of the individual. The manner in which the multiple sources of information are weighted and combined influences the resulting self-efficacy. Some sources have a direct linear influence, as is the case with mastery experiences. Other factors may have a curvilinear relationship to self-efficacy and performance. For example, moderate levels of arousal may contribute to higher performance, but low or high levels of arousal may impede performance. It must be remembered as well that these sources operate congruently. Individuals often experience success or failure in an endeavor while at the same time observing others engaging in the same activity. It is also possible, if not likely, for an individual to receive feedback that constitutes social persuasion and to experience physiological and affective states during and after an experience that will be integrated into future self-efficacy beliefs. It is this cognitive processing and integration of information from multiple sources that determines an individual's self-efficacy beliefs.

Consistent with Bandura's (1997) theory, researchers have reported significant correlations ranging from .20 to .78. among the four sources themselves (Lent, Lopez, & Bieschke, 1991; Lent, Lopez, Brown, & Gore, 1996; Matsui, Matsui, & Ohnishi, 1990; Usher & Pajares, in press). Most researchers have found that each of the sources correlates with self-efficacy (Anderson & Betz, 2001, Klassen, 2004; Lent et al., 1991; Lent, Lopez, et al., 1996; Lopez, Lent, Brown, & Gore, 1997). Many of the studies have primarily been conducted with high school and college students in the area of mathematics (Lent, Lopez, et al., 1996; Matsui et al., 1990). Some of this research has focused on the role played by mathematics self-efficacy in predicting science-related course taking and career choices (Lent et al., 1991).

As Bandura (1986, 1997) hypothesized, mastery experiences typically prove to be the strongest and most consistent predictor of academic self-efficacy (Hampton, 1998; Klassen, 2004; Lent, Brown, Gover, & Nijjer, 1996; Lent et al., 1991; Lent, Lopez, et al., 1996; Lopez & Lent, 1992; Matsui et al., 1990; Usher & Pajares, in press). For example, Lent et al. (1991) found that mastery experience was the only significant predictor of the mathematics self-efficacy of undergraduate students, contributing 36% of the variance. One problem in the measurement of mastery experience is that some researchers have operationalized this as actual obtained performance. For example, Matsui et al. (1990) investigated the sources of mathematics self-efficacy in Japanese undergraduates using students' reports of their actual high school mathematics grade as the measure of mastery experiences. This is problematic because it does not incorporate students' interpretation of previous mastery experiences. Bandura (1997) viewed this cognitive interpretation of experience as an essential aspect of the development of self-efficacy.

The other sources of self-efficacy information theorized by Bandura (1997) have proved less consistent as predictors of self-efficacy when each of the sources is controlled (Hampton, 1998; Lent et al., 1991; Lopez & Lent, 1992; Matsui et al., 1990). Some researchers have found that vicarious experiences predict academic self-efficacy (Hampton, 1998; Matsui et al., 1990; Usher & Pajares, in press); others have reported no such influence (Lent et al., 1991; Lopez & Lent, 1992). The same is true for physiological states, with some researchers reporting that this source makes an independent contribution to the prediction of mathematics self-efficacy (Lopez & Lent, 1992; Matsui et al., 1990) and some reporting that it does not (Lent et al., 1991). Similar inconsistencies have been reported regarding the predictive influence of social persuasions, which some have found predictive (Usher & Pajares, in press), whereas others have not (Hampton, 1998; Lent et al., 1991; Lopez & Lent, 1992; Matsui et al., 1990). In some cases, the influence of a particular source varies by group membership, but findings on this score are inconsistent as well. For example, Usher and Pajares (in press) reported that social persuasions predicted the academic self-efficacy of girls, whereas vicarious experience and physiological states did not; conversely, both vicarious experience and physiological state predicted the self-efficacy of boys, whereas social persuasions did not. Alternatively, Anderson and Betz (2001) reported that social persuasions predicted the social confidence of undergraduate men but did not predict men's or women's social self-efficacy.

These inconsistent findings may be due to some of the methodological choices made by researchers. Some have used stepwise or hierarchical regression models in which variables are entered according to what what is referred to as the variables' "relative potency" (e.g., Hampton, 1998; Lent et al., 1991; Lopez & Lent, 1992; Matsui et al., 1990). In these cases, mastery experience is entered first, with vicarious experience, social persuasions, and physiological state following in that order. This ordering takes place even when correlations between the sources do not match the presumed order in a particular study. But it is important to emphasize that such ordering has no theoretical support. Although Bandura (1997) contended that interpreted mastery

experience is the most powerful source of efficacy information, he does not speak to the relative contribution of the other three sources. Such problematic methodological practices have made it difficult to sift out the independent contribution each source makes to the prediction of self-efficacy.

Given the varying results obtained for the predictive utility of the four sources of self-efficacy, Lent, Lopez, et al. (1996) sought to clarify the latent structure of Bandura's (1997) hypothesized four sources, testing four possible structures with high school and college students. Among the college students, Bandura's model of four distinct sources of self-efficacy information provided the best fit to the data. Results differed slightly with the high school sample, with a five-factor model providing a better fit for the high school data. In this model the influence of social persuasions from peers was separated from social persuasions from adults. The authors speculated that high school students may be more sensitive to differences in input from peers and adults. Usher and Pajares (in press) similarly obtained a five-factor solution with a sample of grade 6 students.

Some researchers have found gender differences in the sources of self-efficacy. Some have reported that, among middle school, high school, and college students, women report stronger vicarious experiences and social persuasions than do men (Anderson & Betz, 2001; Lent, Lopez, et al., 1996; Usher & Pajares, in press). Others, however, have failed to find significant gender differences in the sources (Lent et al., 1991; Matsui et al., 1990).

Potential influences on students' academic self-beliefs are particularly important during the middle school years, as the transition from elementary to middle/junior high school often introduces a larger social comparison group, a greater emphasis on grades and competition, and a larger, less personal environment (Eccles et al., 1989; Harter, Whitesell, & Kowalski, 1992). Research on the sources of self-efficacy beliefs will provide influential adults in these young peoples' lives with information needed to support optimal development of science self-efficacy beliefs.

Given the findings discussed above, our objectives in the current study were threefold. First, in an effort to replicate previous findings related to self-efficacy and motivation, we sought to determine whether self-efficacy makes an independent contribution to the prediction of science achievement when other variables found to predict achievement are controlled. To accomplish this, we included constructs currently used in studies of academic motivation. The constructs are self-efficacy for use of self-regulatory practices (Zimmerman, Bandura, & Martinez-Pons, 1992), self-concept (Marsh, 1990), and anxiety (Pajares & Urdan, 1996). Our second and primary goal was to determine the degree to which each of the four hypothesized sources of self-efficacy makes an independent contribution to students' science self-efficacy. Third, because gender differences are typically reported in studies of academic self-efficacy beliefs, we investigated whether the sources of science self-efficacy differ as a function of gender. We used Bandura's (1986) social cognitive theory as a theoretical framework and interpret results from that perspective.

Method

Participants and Procedures

Participants were 319 students (155 boys, 164 girls) in grades 5–8 in a public middle school in a small midwestern city. The socioeconomic status of the area served by the school was largely middle class, and the students were primarily White. The school was selected because the science program is a hands-on program that has resulted in student science achievement that is higher than in other schools in the district and state. Instruments were group administered by the first author

and two research assistants in individual science classes near the end of the last grading period of the academic year. Teachers provided students' grade point average (GPA) in science class. Written permission to gather data was provided by the students' parents and by the school administration. Procedures were similar to those used by self-efficacy researchers (see, e.g., Pajares et al., 2000; Pajares, Miller, & Johnson, 1999; Shell et al., 1995).

Instruments and Variables

The *sources of science self-efficacy* were assessed with the Sources of Science Self-Efficacy Scale, which was adapted from a scale used to measure this construct in the domain of mathematics (see Lent, Lopez, et al., 1996). It consists of four subscales measuring the effects of mastery experiences (eight items; sample: ''I got a good grade in science class last semester''), vicarious experiences (seven items; sample: ''Many of the adults I most admire are good in science''), social persuasions (eight items; sample: ''My teachers believe I can do well in difficult science courses''), and physiological states (eight items; sample: ''Science makes me feel uncomfortable and nervous'').

As did Lent, Lopez, et al. (1996), we conducted exploratory factor analysis (EFA) to identify the latent constructs underlying the sources items on each scale. We followed guidelines for implementing factor analysis recommended by Fabrigar, Wegener, MacCallum, and Strahan (1999). Specifically, we considered the design of the study, adequacy of the sample size, and appropriateness of factor analysis and specific techniques used. We also employed multiple criteria for selecting the number of factors and used the maximum likelihood method of extraction (Jöreskog & Lawley, 1968) because this is the method believed to produce the best parameter estimates (Pedhazur, 1982). All analyses were conducted using the SAS system's FACTOR procedure (SAS Institute, Inc, 1999). We used the recommended oblique rotation method, and we employed the scree test (Cattell, 1966) and the interpretability of the rotated factors to help us determine the number of common factors to retain and analyze. Items on each scale loaded on one factor. Loadings for the mastery experience items ranged from .60 to .81; for the vicarious experience from .47 to .72; for the social persuasions from .55 to .85; and for the physiological index from .66 to .88. Cronbach's alpha reliability indexes were .90 for mastery, .80 for vicarious, .88 for social persuasions, and .91 for physiological states.

Science grade self-efficacy was assessed with five items that asked students to provide a rating of their confidence that they could earn either an A, B, C, or D in their science class (sample: ''How confident are you that you will get an A?'') (see Bandura, 1997, for assessment procedures consistent with tenets of self-efficacy theory). Researchers have reported alpha coefficients ranging from .69 to .85 when academic self-efficacy has been measured in a similar way. Britner and Pajares (2001) reported .86 for science self-efficacy. We obtained .85.

Science self-concept is students' perceptions about their science ability and their feelings of self-worth associated with this ability. It was assessed with the six-item science scale from Marsh's (1990) Academic Self Description Questionnaire (ASDQ-1) (sample: ''Science is easy for me''). Marsh obtained alpha coefficients ranging from .88 to .94 on the 13 subject scales in the ASDQ-1, including the science scale. Britner and Pajares (2001) obtained a Cronbach's alpha coefficient of .82. We obtained a coefficient of .89.

Science anxiety is feelings of tension and stress that interfere with the construction of science knowledge, the development of science skills and abilities, and the use of science knowledge, skills, and abilities in life and in academic situations (Mallow, 1981; Richardson & Suinn, 1972). The eight-item science anxiety scale asked students to consider statements about comfort or anxiety with science and to indicate the degree to which these statements reflected their feelings

about science (''Science makes me feel uneasy and confused''). Britner and Pajares (2001) obtained a Cronbach's alpha coefficient of .63 using this scale adapted for middle school science. We obtained a coefficient of .91.

Self-efficacy for self-regulated learning was assessed using a seven-item subscale adapted from Bandura's Children's Multidimensional Self-Efficacy Scales that assesses students' judgments of their capability to use various self-regulated learning strategies (sample: ''How well can you finish your homework on time?'') (Zimmerman & Bandura, 1994). A validation study by Zimmerman and Martinez-Pons (1988) revealed that a single factor underlay the items. Researchers have reported Cronbach's alpha coefficients ranging from .80 to .87 (Pajares, 1996; Pajares et al., 1999; Zimmerman et al., 1992). We obtained a coefficient of .78.

Science achievement was operationalized as students' grade in science class at the end of the grading period in which this study was conducted. Grades were provided by the students' teachers and ranged from F (0) to A (4).

Analysis

To investigate whether motivation and achievement in science differ as a function of gender, we conducted multivariate analyses of covariance (MANCOVA) using prior achievement, in the form of students' science grades from the previous semester, as a covariate. Multiple regression analyses were conducted to determine (a) the degree to which each of the hypothesized sources of self-efficacy makes an independent contribution to the prediction of science self-efficacy, and (b) whether science self-efficacy predicts science achievement when other variables found to predict achievement are controlled. Separate analyses were conducted for the total sample and by gender. These analyses were supplemented by a regression commonality analysis (Rowell, 1996) and by obtaining regression structure coefficients (Thompson & Bordello, 1985). Commonality analysis provides a uniqueness indicator that can be used to determine the proportion of the explained variance of a dependent variable associated uniquely with an independent variable. Unlike the beta coefficients typically reported in multiple regression analyses, structure coefficients, the zero-order correlation between a dependent and an independent variable divided by the multiple correlation, are not suppressed or inflated by collinearity between the independent variables. All analyses were conducted using the SAS system, Version 8 (SAS Institute, Inc, 1999).

Results

Means, standard deviations, and correlations are provided in Table 1. Consistent with the tenets of self-efficacy theory, each of the hypothesized sources of self-efficacy significantly correlated with science self-efficacy, with each other, and with students' grades obtained in science. MANCOVA results revealed a significant multivariate effect for gender, Wilks' lambda = .77, $F(9, 307) = 9.92$; $p < .0001$ (see Table 2). At similar levels of prior achievement, girls had higher science grades (3.3 to 3.1) than did boys, but girls and boys reported equal self-efficacy. Boys reported stronger mastery experiences (4.2 to 3.9) than did girls. Girls reported higher levels of self-efficacy for self-regulation (4.7 to 4.3) as well as higher science anxiety and physiological states (2.6 to 2.2).

Results of the regression analyses predicting science grade are provided in Table 3. Science self-efficacy was the most consistent predictor of students' science grade. For the full sample, self-efficacy ($\beta = .480$) and self-concept ($\beta = .260$) predicted students' science grade, $F(5, 313) = 40.46$, $p < .0001$, $R^2 = .39$. For boys, science grade was predicted only by science self-efficacy ($\beta = .569$), $F(5, 149) = 20.66$, $p < .0001$, $R^2 = .41$. For girls, science self-efficacy ($\beta = .481$) and

Table 1
Means, standard deviations, and zero-order correlations for variables in the study

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12
1. Mastery	4.0	1.2	—											
2. Vicarious	3.3	1.0	.63***	—										
3. Persuasion	3.8	1.0	.73***	.73***	—									
4. Physiological	2.4	1.1	-.66****	-.39****	-.44***	—								
5. Self-efficacy	5.0	0.9	.55****	.34****	.42****	-.40***	—							
6. Engagement	4.4	1.2	.39****	.50****	.46****	-.31****	.20**	—						
7. Self-concept	4.4	1.1	.82****	.59****	.67****	-.72****	.61****	.43***	—					
8. Anxiety	2.4	1.1	-.66****	-.39****	-.44****	1.00****	-.40****	-.31****	-.72***	—				
9. Self-reg	4.5	0.9	.47****	.41****	.49****	-.41****	.44****	.46****	.52****	-.41***	—			
10. Post-GPA	3.2	0.8	.48****	.26****	.40****	-.28****	.60****	.20**	.49****	-.28****	.32***	—		
11. Pre-GPA	3.2	0.8	.46****	.26****	.36****	-.25****	.64****	.21***	.48****	-.25****	.33****	.70***	—	
12. Gender	0.5	0.5	.13*	-.04	.02	-.16*	.04	-.01	.04	-.16*	-.22***	-.14*	-.10	—

Note: Means for all variables with the exception of GPA and Gender reflect the six points of the Likert scale. GPA scores ranged from 0(F) to 4(A). Gender was coded 0 for females and 1 for males. $*p < .05$, $**p < .001$, $***p < .0001$.

Table 2

Means for variables in study for full sample and by gender

	Full Sample	Boys	Girls
Mastery	4.0	4.2a	3.9b
Vicarious	3.3	3.3	3.4
Persuasion	3.8	3.8	3.8
Physiological	2.4	2.2a	2.6b
Self-Efficacy	5.0	5.0	5.0
Engagement	4.4	4.4	4.5
Self-Concept	4.4	4.5	4.4
Anxiety	2.4	2.2a	2.6b
Self-Reg	4.5	4.3a	4.7b
Postpga	3.2	3.1a	3.3b

Note: Means by gender are adjusted means obtained from MANCOVA results. Group means for a dependent variable (row) that are subscripted by different letters are statistically different (experimentwise $\alpha < .05$).

science self-concept ($\beta = .278$) predicted their science grade, $F(5, 158) = 24.43$, $p < .0001$, $R^2 = .44$. However, uniqueness indicators indicated that self-efficacy accounted for the largest share of the unique variance.

Table 4 provides the results of the regression analyses predicting science self-efficacy for the full sample and by gender. Of the four sources, only mastery experience significantly predicted science self-efficacy ($\beta = .494$ for the full sample, $\beta = .403$ for boys, $\beta = .598$ for girls). Structure coefficients and uniqueness indicators confirmed these results, with mastery experiences contributing the largest percentage of the unique variance in each case (24% for the full sample, 17% for boys, 35% for girls) and the other three sources making only minor contributions.

Discussion

The primary aim of our study was to determine the degree to which each of the four hypothesized sources of self-efficacy makes an independent contribution to the science self-efficacy beliefs of middle school students. Ours is the first investigation to address this important question in the area of science. We also sought to explore the ways in which science self-efficacy and the sources that inform its development differ as a function of gender. We first replicated

Table 3

Standardized regression coefficients, structure coefficients, and uniqueness indicators for the prediction of science grade for total sample and by gender

	Full Sample		Boys		Girls	
	β (SC)	U	β (SC)	U	β (SC)	U
Self-efficacy	.480*** (.962)	34%	.569*** (.961)	41%	.481*** (.935)	33%
Engagement	*ns* (.321)	1%	*ns* (.373)	3%	*ns* (.256)	1%
Self-concept	.260** (.785)	5%	*ns* (.728)	3%	.278* (.799)	6%
Anxiety	*ns* (−.465)	1%	*ns* (−.381)	4%	*ns* (−.588)	1%
Self-reg	*ns* (.513)	10%	*ns* (.488)	1%	*ns* (.422)	2%
R^2	.39***		.41***		.44***	

Note: Structure coefficients (SC) are in parentheses following beta coefficients. *U* represents the percentage of the explained variance (R^2) in the dependent variable associated uniquely with the independent variable. *$p < .05$, **$p < .001$, ***$p < .0001$.

Table 4

Standardized regression coefficients, structure coefficients, and uniqueness indicators for the prediction of science self-efficacy for total sample and by gender

	Full Sample		Boys		Girls	
	β (SC)	U	β (SC)	U	β (SC)	U
Mastery	.494*** (.987)	24%	.403** (.963)	17%	.598*** (.991)	35%
Vicarious	ns (.610)	0%	ns (.662)	1%	ns (.557)	1%
Persuasion	ns (.754)	0%	ns (.750)	3%	ns (.728)	1%
Physiological	ns (−.718)	0%	ns (−.772)	6%	ns (−.653)	1%
R^2	.31***		.35***		.30***	

Note: Structure coefficients (SC) are in parentheses following beta coefficients. *U* represents the percentage of the explained variance (R^2) in the dependent variable associated uniquely with the independent variable. *$p < .05$, **$p < .001$, ***$p < .0001$.

earlier findings to confirm that science self-efficacy is a significant predictor of science achievement. Such a finding is, of course, a logical precursor to our investigation of the sources. Exploring the antecedents of self-efficacy beliefs would have limited value if those beliefs were not shown to be important influences on students' academic achievement.

Gender differences found in the variables were minimal and consistent with those found in previous studies of science self-efficacy (Britner & Pajares, 2001; Pajares et al., 1999). Girls reported more anxiety about their performance in science class and more confidence in their ability to successfully manage their studies. The girls earned higher final science grades than did the boys, a not uncommon phenomenon at this level. We have speculated in earlier studies that this may be a function of girls' greater facility with language (Britner & Pajares, 2001). In middle school, science classes are often taught more with language-related methods than with investigative or laboratory methods, thus enabling the strengths girls develop in the elementary years to carry them through middle school science experiences. However, girls' higher levels of success in science did not result in their reporting more mastery experiences (higher in boys) or in the development of stronger science self-efficacy (equal in boys and girls) or science self-concept (higher in boys).

Results also support Bandura's (1997) hypothesized sources of self-efficacy and extend previous research findings into the domain of science. Each of the sources significantly correlated with each other, with science self-efficacy, and with achievement in science. In regression analyses, mastery experiences positively predicted science self-efficacy beliefs, both for the full sample and for the separate analyses of boys and girls, although uniqueness indicators showed that mastery experiences accounted for a greater degree of variance in girls than in boys. The strength of the influence of mastery experiences on science self-efficacy is similar to the effect found in self-efficacy in other academic areas (Hampton, 1998; Lent et al., 1991; Matsui et al., 1990) or in academic self-efficacy in general (Usher & Pajares, in press).

The strong influence of mastery experiences on self-efficacy provides opportunities for science educators to support students' developing self-efficacy beliefs. Middle school science teachers are in a unique position to scaffold children's science development as they move from the textbook-based science instruction common in many elementary classrooms to laboratory-based science classes found in high school. Engaging students in authentic inquiry-oriented science investigations during middle school will provide mastery experiences necessary to the development of strong science self-efficacy beliefs. Science teachers should scaffold these activities, tailoring them to their students' developing abilities, providing the level of challenge that will

facilitate efficacy-building successes and minimize failures that will diminish confidence in new abilities. It is also important to focus on helping students interpret these experiences in ways that bolster rather than diminish self-efficacy beliefs. After all, it is the interpretation of the mastery experiences rather than simply the experiences themselves which have the greatest impact on self-efficacy (Bandura, 1997).

Because vicarious experiences, social persuasions, and physiological arousal were significantly correlated with self-efficacy, they should be considered precursors of students' science self-efficacy beliefs. These sources of self-efficacy provide additional opportunities for science educators to facilitate the development of positive science self-efficacy in middle school students.

Vicarious experiences are important in areas in which students may have limited mastery experiences upon which to base their efficacy judgments (Bandura, 1997). Careful attention to the composition of groups in which students work can provide students with models who are slightly ahead of them in science skills. Science teachers can invite scientists into the classroom to work with students and to share with them the work they do and the paths that led them to careers in science. It is important to remember that modeling is more successful when the observers perceive similarities between themselves and the models. This may be particularly important to young women and minority students who may not often see themselves reflected in the faces of those who do science.

Social persuasions serve as an enhancement to mastery experiences. Students who are told by significant others that they have the ability to master new or difficult science tasks are more likely to persevere in the face of challenges and mobilize the effort needed for efficacy-building successes. However, encouragement given to students must be appropriate and realistic. Encouraging students to attempt tasks significantly beyond their present abilities and knowledge has the potential to lead to disconfirming failures that diminish self-efficacy rather than enhance confidence. Social persuasions must also be genuine to be effective in supporting students' self-efficacy. Students quickly see through false praise. This can lower students' self-efficacy and result in a loss of credibility on the part of adults offering undeserved praise. Bear in mind also Bandura's caution that it is often easier to diminish a student's self-efficacy with negative social persuasions than to enhance it with positive messages. Students who are persuaded that they would not succeed in science may tend to avoid appropriately challenging science activities and give up easily when encountering difficulties. This lack of effort would thus lessen the likelihood of experiencing efficacy-building successes in science.

The interpretation of physiological states is another area in which teachers may affect students' developing self-efficacy. Helping students to control anxieties and fears related to science and pointing out, where appropriate, that negative arousal is not congruent with the students' performance can facilitate the development of positive self-efficacy beliefs, which will in turn, lead to more positive physiological states. As Pajares (2005) has pointed out, students can get a fairly good sense of their confidence by the emotional feelings they experience as they contemplate an action. Negative feelings provide cues that something is amiss, even when one is unaware that such is the case. Students who approach a science activity with apprehension likely lack confidence in their science skills. Moreover, those negative feelings can themselves trigger additional stress and agitation that help ensure the inadequate performance feared. Worse yet, anxiety and dread can be paralyzing. A science teacher can help students read their emotional feelings and help them understand that these feelings should not be ignored. Yet another way to decrease anxiety is to increase a student's attention to the task at hand. Because attention has limited capacity, a mind well focused on the dynamics of a particular activity cannot easily shift that focus to its fears and apprehensions.

As has been established by prior research and confirmed with this sample of middle school students, self-efficacy is a strong predictor of achievement in science. Because self-efficacy influences academic achievement, a drop in confidence during the middle school years can have a negative influence on students' high school and college achievement. Of particular concern to science educators is that failure to take science and mathematics courses because of low self-efficacy can block the pursuit of careers in mathematics and science (Zeldin & Pajares, 2000). Careful attention to the sources of self-efficacy is thus one way in which teachers and parents can increase students' success in science and ensure that course-taking and career decisions are based, not on a lack of confidence or fear of science, but rather on the basis of interests and ability.

Future investigations should extend this research to students in other educational levels and in different socioeconomic and ethnic groups. Given the disproportionally low numbers of students of color pursuing science careers, it would be fruitful to investigate sources of science self-efficacy in schools with more ethnically diverse populations. Also, the achievement variable used in this investigation was the students' end-of-semester science grade. Overall course grades in science are calculated from a variety of instructional activities, including more traditional approaches such as lecture, demonstrations, homework, and tests as well as laboratory or inquiry-oriented approaches. It may well be that the sources of self-efficacy work differently in these varying types of activities. Increased understanding of the antecedents of self-efficacy across age-groups and settings will assist science educators in facilitating student interest and success in science-related activities and careers.

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