Engaging Students

An Examination of the Effects of Teaching Strategies on Self-Efficacy and Course Climate in a Nonmajors Physics Course

By Heidi Fencl and Karen Scheel

Self-efficacy is a key predictor of achievement and retention in most academic areas, including the sciences. In this study, the effects of teaching strategies on self-efficacy and course climate were examined. Question and answer, collaborative learning, conceptual problems, electronic applications, and inquiry labs were found to make significant, unique contributions to self-efficacy and/or classroom climate.

Self-efficacy (Bandura 1977) is a person's situation-specific belief that he or she can succeed in a given domain. It has been successful in educational and vocational psychology studies at predicting success (as measured by grades) and persistence. Lent, Brown, and Larkin (1987) compared self-efficacy theory to interest congruence (agreement between a person's interests and those of practitioners in the field) and consequence thinking (anticipation of major consequences in decision-making processes) for 105 students in a career/education planning class for potential science and related majors and found self-efficacy to be the most useful predictor of the three for both grades and persistence. Hackett et al. (1992) found that self-efficacy was a stronger predictor of cumulative college GPA than interest, outcome expectations, and stress, strain, and coping for a sample of 197 undergraduate engineering majors. Shaw (2004) found that physics self-efficacy correlated with course grade for women in an algebra-based physics course (but not for men in that course or for students in a conceptual or a calculus-based course.)

Self-efficacy is not a static attribute, but is affected by a person's experiences and is postulated to change according to four sources—emotional arousal (EA), vicarious learning (VL), performance accomplishment (PA), and social persuasion (SP) (Bandura 1977; Bandura 1986; Betz and Hackett 1981). Few studies have been done to examine the effect of science classroom experiences on self-efficacy. Baldwin, Ebert-May, and Burns (1999) found some pedagogies including cooperative learning to be effective for overall self-efficacy of students in an undergraduate biology course, although Cassidy and Eachus (2000) did not find a correlation between self-efficacy and perceived proficiency for students in a research methods course for health care and social workers. Neither study explored the effect of particular teaching strategies through the four sources of efficacy. Fencl and Scheel found that some pedagogies, most notably collaborative learning, positively contributed to the self-efficacy of students in introductory physics (Fencl and Scheel 2004) and chemistry (Scheel et al. 2002) courses for physical science majors; and Samiullah (1995) found improved student attitudes and environment for students in a first-semester algebra-based physics course that included increased student-student interactions over the control group.

Exploration of self-efficacy

Given the success of self-efficacy theory for predicting student success in scientific study, and the demonstrated effect that teaching approaches have on student self-efficacy in majors courses, the purpose of this study is to ask if similar relationships between pedagogy and self-efficacy exist in introductory science courses for non–physical science majors. In particular, this study proposes to identify which, if any, teaching approaches affect student self-efficacy in physics, and to identify the sources of efficacy through which those pedagogies have their effect. An additional goal of the study is to probe the relationship among teaching approaches, course climate, and student confidence.

Method: A three-part student survey instrument was developed to gather information about the course, physics self-efficacy, and demographics. Demographic information includ-

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ed math background, ACT score, GPA, race/ethnicity, age, sex, and major.

Students provided course information by rating the frequency with which they were taught by seven traditional and seven alternative teaching strategies; they also responded to seven classroom climate questions. Traditional strategies included lecture, question and answer, quantitative lab exercises, directed lab exercises, quantitative problem assignments, demonstration, and audio-visual presentations. Alternative teaching strategies included discussion, collaborative learning, conceptual lab exercises, inquiry-based lab exercises, conceptual problem assignments, desktop activities, and electronic applications.

Climate items assessed students' perceptions of the supportiveness of classmates and the instructor, and the instructor's responsiveness and accessibility to students. The six-item climate scale had an internal consistency reliability alpha coefficient of .71 for this sample. One climate item, "Students in the class competed against each other for grades," was dropped from analysis. It was expected to be a negative item yet responses of students in calculus-based physics showed a positive correlation between grade competition and overall climate score (Fencl and Scheel 2004).

Self-efficacy information was collected for each student through a 33-item Sources of Self-efficacy in Science Courses—Physics (SOSESC-P) instrument, modeled by the authors after existing sources measures and designed to probe the four sources of self-efficacy as described above. Internal consistency reliability alpha coefficients were adequate to strong for the sample, ranging from .68 (SP) to .88 (EA); the coefficient for the total scale was .94. In addition, all SOSESC-P subscales and the total scale correlated significantly and positively in this sample with scores on the Self-Efficacy for Academic Milestones-Strength scale (Brown, Lent, and Larkin 1986), an established measure of global self-efficacy in science and engineering. Students also indicated their interest and expected grade in the course, how their confidence in their ability to do science changed as a result of the course, their desire to drop it if not required, and their future science-related plans. Instructors also completed a one-page questionnaire about teaching in the course and their professional and demographic characteristics.

Sample: The student and instructor questionnaires were given to voluntary participants in five first-semester algebra-based physics courses at four-year campuses in a state university system. Class sizes ranged from 42 to 68 students, with an average of 56 students. Traditional teaching strategies were used most frequently throughout all courses sampled.

Two hundred and eighteen students (131 women and 87 men) completed the student questionnaire. Students ranged in age from 18 to 45, with a mean age of 21. Of these students, 90.4% were European American, 4.1% Asian/Pacific Islander, and the rest of the students African American, Hispanic, or of mixed ethnicity. The majority of the students were upper class students (70.6%) and more than

TABLE 1

Self-efficacy values for the sample group (rated on a 5-point scale, where 1 indicates relatively low self-efficacy and 5 indicates high self-efficacy).

Scale or subscale	Mean	Standard deviation
Total SOSESC-P	3.57	.56
EA	3.20	.77
VL	3.70	.63
PA	3.63	.57
SP	3.81	.51

TABLE 2

Bivariate correlations for teaching strategies significantly ($p < .05$) related to self-efficacy scores and subscores. *Indicates a teaching strategy significantly and uniquely related to the indicated score, as given by multiple regression analyses controlling for math background and ACT score.

Teaching strategy	SOSESC-P	EA	VL	PA	SP
Question and answer	.33*	.30*	.34*	.27*	.27
Collaborative learning	.28	.22	.24	.22	.34*
Electronic applications	.27*	.26*	.29*	.21*	.21
Conceptual problem assignments	.24*	.19*	.20*	.20*	.24
Quantitative problem assignments	.17		.19	.15	.21
Discussion	.16	.14			.25
Inquiry lab activities					.24*
Conceptual lab activities					.22
Demonstration					.16
Desktop activities					.16

half were biological science majors (51.8%). Other majors included applied science, technology, chemistry, mathematics, engineering, and "other." Most (90.4%) of the students were required to take the course.

One of the instructors was female. Instructors' experience averaged 11 semesters with this particular course, and 14 years of college teaching experience.

Results—Self-Efficacy: Mean self-efficacy values for the students completing the survey are given in Table 1, page 21. Two demographic variables—ACT score and math background—were found to positively correlate with SOSESC-P subscales and so were controlled in subsequent regression analyses. Neither class size nor gender was found to be a significant confounding variable.

As shown in Table 2, page 21, all nontraditional teaching strategies and many traditional strategies significantly correlated with one or more self-efficacy scores, as measured by the SOSESC-P. Lecture, quantitative and directed lab activities, and AV presentations were the only four strategies that did not correlate with at least one self-efficacy subscale. Multiple-regression analyses were performed to determine if significantly correlated teaching strategies as a block account for variance in self-efficacy scores beyond that due to ACT score and prior math background, and to identify which strategies significantly and uniquely correlate with self-efficacy measures. In all five cases (total SOSESC-P and all sub-scales), teaching pedagogies were found to contribute to variance beyond that of ACT and math background. Teaching strategies accounted for 18% of variance in SOSESC-P, as compared to 8% variance for ACT and math background. Similar variance values for EA, VL, and SP are 15% and 5%, 17% and 7%, and 21% and 2%, respectively. Teaching strategies accounted for 13% of variance in PA, as compared with 13% for math background and ACT.

Results—Climate: The overall mean climate score for students completing the survey was 3.94 (standard deviation = .60) on a 5-point scale, with larger numbers indicating more positive course climate. ACT score (but not mathematics background, class size, or gender) confounded with climate and was therefore controlled in regression analysis.

As was the case with self-efficacy measures, some teaching strategies were found to significantly correlate with course climate. Ten of these strategies showed positive correlations, and one (directed lab activities) showed a significant negative correlation (Table 3). Three strategies (lecture, quantitative lab activities, and AV presentations) did not correlate significantly with course climate. Multiple-regression analysis found that teaching strategies accounted for 28% of the variance in climate effect, as compared with 4% of variance from ACT score, for a total of 32% variance.

Results—Effect of Self-Efficacy: Mean confidence change, as measured by the question "Has your confidence level in your ability to do science changed as a result of taking this course?", was 3.51 (a score of 5 indicated a large positive change in confidence), with a standard deviation of .95. Neither mathematics background, ACT score, gender, nor class size was found to be significantly associated with confidence change. Both self-efficacy and course climate, however, were significantly correlated with confidence change and with each other. In the bivariate analysis, SOSESC-P total score accounted for 37% of variance, and climate score for 13%, in confidence change. In regression analysis, self-efficacy and climate together accounted for 38% of variance in confidence change. Only self-efficacy was a significant unique predictor, suggesting that course climate is only indirectly related to confidence change (through its relationship with self-efficacy.)

Self-efficacy also correlated with students' interest in the course ($r = .48, p < .001$), future plans ($r = .20, p < .005$), expected grades ($r = .57, p < .001$), and desires to drop the course ($r = -.61, p < .001$).

TABLE 3

Correlation coefficients for teaching strategies significantly ($p < .05$) related to course climate. *Indicates a teaching strategy significantly and uniquely related to class climate.

Teaching strategy	Correlation with course climate
Question and answer*	.34
Inquiry lab activities*	.30
Conceptual problem assignments*	.27
Collaborative learning	.24
Discussion	.22
Quantitative problem assignments	.22
Demonstration	.21
Desktop activities	.20
Electronic applications	.20
Conceptual lab activities	.16
Directed lab activities*	−.15

Discussion

The relationships found here for nonphysics majors between physics self-efficacy and outcome variables including expected course grade and future science-related plans are very much in line with other explorations and indicate that self-efficacy is, indeed, an important attribute for understanding students' performances in introductory physics. For instructors of such courses, it is particularly exciting to note that the teaching strategies used in the classroom can and do make a difference to students' self-efficacy. What is more, the size of the effect that teaching strategies have on self-efficacy is meaningful both given the vast array of experiences that students have and also compared to other effects (ACT score and previous math background).

Teaching strategies that were found to be especially beneficial to self-efficacy include question and answer, collaborative learning, electronic applications, and conceptual problem assignments. Question and answer, inquiry labs, and conceptual problem assignments were found to have unique and significant positive effects on classroom climate. These strategies share the feature of engaging students either creatively or comfortably in the learning process. Most (especially collaborative learning and inquiry labs) have also been shown to have positive effects on how well students learn physics content. Instructors, then, who adopt such teaching approaches in their classrooms have a positive effect on both self-efficacy and its associated outcome variables and on variables related to student learning. Any potential causal relationship between the two types of variables has yet to be explored; such an exploration may shed additional light on questions regarding the importance of student attitude for learning.

The above paragraphs refer to science classrooms without specific reference to introductory physics for non–physical science majors. Studies of students in both introductory physics and introductory chemistry courses for physical science majors also found that teaching strategies affect self-efficacy, and with similar effect size (Fencl and Scheel 2004; Scheel et al. 2002). This gives good reason to believe the general results apply across introductory science courses and across student majors. One key difference between this study and those for physical science majors, however, is the importance of the role played by collaborative learning. In both of the majors' courses, collaborative learning emerged as the single most import teaching strategy for the development of self-efficacy in students. There are several possible reasons for the comparatively weaker performance of collaborative learning found in this study.

It is possible that the results reflect a real difference between the two populations and that collaborative learning has a greater effect on self-efficacy for students in the majors courses than in courses for nonmajors. This could suggest, for example, that students are more comfortable with passive learning strategies in courses that are not part of their major.

An alternate explanation is that the stronger performance of other teaching strategies found in this sample, especially question and answer—with which collaborative learning was significantly related ($r = .46, p < .001$), reduces the likelihood of either strategy emerging as a unique predictor in regression analysis. This statistical inter-relationship may also reflect a real effect in the way that the teaching strategies were used in the courses sampled. For example, in one section a large portion of collaborative learning time was spent working on conceptual questions, and students were allowed to talk with the instructor in addition to each other. In other words, at least three different teaching strategies were wrapped together in students' experiences. It is plausible that such multiple usages are common in other courses and are especially common in courses that make much use of student-active teaching strategies.

Finally, attention needs to be given to understanding the interactions among climate, self-efficacy, and confidence change. Significant correlations were found between each pair, with moderate effect sizes for self-efficacy and climate and for self-efficacy and confidence change. A low-moderate correlation was found between climate and confidence change. In other words, in addition to being affected by teaching strategies, class climate and self-efficacy scores also go up together (especially through the more socially-related subscales of SP and VL, which have correlation coefficients of .64 and .53, respectively.) Both self-efficacy and course climate affect students' confidence change in their abilities to do science. Regression analysis suggests that the climate affects confidence through the above-mentioned influence with self-efficacy.

Conclusion

Science education research has shown the importance of engaging students actively in the learning process if they are to make gains in their understanding of the physical world. This study looks at engagement of nonmajor students from the perspective of self-efficacy. Active strategies that require students to interact socially or to creatively and qualitatively work with course content are the most effective at building students' physics self-efficacies. This is an important result for instructors, because outcome variables including changes in confidence, interest in physics, anticipated grade, and future science study and career plans all were found to be positively linked with self-efficacy.

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References

Baldwin, J., D. Ebert-May, and D. Burns. 1999. The development of a college biology self-efficacy instrument for non-majors. *Science Education* 83 (4): 397–408.

Bandura, A. 1977. Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review* 84 (2):191–215.

Bandura, A. 1986. *Social foundation of thought and action: Social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

Betz, N.E. and G. Hackett. 1981. The relationship of career-related self-efficacy expectations to perceived career options in college women and men. *Journal of Counseling Psychology* 28 (5): 399–410.

Brown, S.D., R.W. Lent, and K.C. Larkin. 1989. Self-efficacy as a moderator of scholastic aptitude-academic performance relationships. *Journal of Vocational Behavior* 35 (1): 64–75.

Cassidy, S., and P. Eachus. 2000. Learning style, academic belief systems, self-reported student proficiency and academic achievement in higher education. *Education Psychology* 20 (3): 307–320.

Fencl, H., and K. Scheel. 2004. Pedagogical approaches, contextual variables, and the development of student self-efficacy in undergraduate physics courses. J. Marx, S. Franklin, and K. Cummings (eds.), *2003 Physics Education Research Conference: AIP Conference Proceedings* (720): 173–176, Melville, NY: AIP.

Hackett, G., N.E. Betz, J.M. Casas, and I.A. Rocha-Singh. 1992. Gender, ethnicity, and social cognitive factors predicting the academic achievement of students in engineering. *Journal of Counseling Psychology* 39 (4): 527–538.

Lent, R.W., S.D. Brown, and K.C. Larkin. 1987. Comparison of three theoretically derived variables in predicting career and academic behavior: Self-efficacy, interest congruence, and consequence thinking. *Journal of Counseling Psychology* 34 (3): 293–298.

Samiullah, M. 1995. Effect of in-class student-student interaction on the learning of physics in a college physics course. *American Journal of Physics* 63 (10): 944–950.

Scheel, K., H. Fencl, M. Mousavi, and K. Reighard. 2002. Teaching strategies as sources of self-efficacy in introductory chemistry. Annual Convention of the American Psychological Association, Chicago, IL.

Shaw, K. 2004. The development of a physics self-efficacy instrument for use in the introductory classroom. J. Marx, S. Franklin, and K. Cummings (eds.), *2003 Physics Education Research Conference: AIP Conference Proceedings* (720): 173–176, Melville, NY: AIP.