Pedagogical approaches, contextual variables, and the development of student self-efficacy in undergraduate physics courses

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Abstract: Self-efficacy, or a person's situation-specific belief that s/he can succeed in a given task, has been successful in a variety of educational studies for predicting behaviors such as perseverance and success (grades), and for understanding which behaviors are attempted or avoided. The focus of this study was to examine if classroom factors such as teaching strategies and classroom climate contribute to students' physics self-efficacy. 121 undergraduates in first semester, calculus-based introductory physics courses completed surveys assessing course experiences, self-efficacy and other outcome variables, and demographic information. Students in sections including a mix of teaching strategies did significantly better than students in the traditional section on outcome variables including self-efficacy. When individual strategies were examined, the strongest relationships were found between cooperative learning strategies and all sources of self-efficacy, and between climate variables and all sources of efficacy.

I. Introduction

Physics Education Research (PER) has a rich history of exploring common misconceptions and areas of difficulty for students in introductory physics courses and of applying that research to the development of materials and approaches for use in the classroom. PER-developed approaches have demonstrated a great deal of success, as evidenced, for example, by student performance on both traditional numerical problems and on probing conceptual questions.

This overall approach taken by PER researchers is grounded in the fact that students do not come to physics classrooms as blank slates, devoid of any prior physical knowledge. They have spent their lifetimes experiencing the physical world and building models to understand those experiences. The power of such experience-based models is demonstrated again and again as students rely on them, rather than on formalized models taught in class, to answer physics-related questions.

It is also true that students do not exist in science classrooms with blank social and emotional slates. It is reasonable to expect that past and current experiences in the *community* of science are just as powerful for retention, perseverance, satisfaction, or confidence (e.g. [1]-[4]) as prior *physical* experiences are for modeling.

educational vocational Research in and psychology has found that self-efficacy is very effective for explaining perseverance and success across the educational spectrum, including undergraduate education and science-related majors (e.g. [5]-[7]). Self-efficacy [8] is a person's situation-specific belief that s/he can succeed in a given task; this belief influences which behaviors are attempted or avoided. Selfefficacy is not a static attribute, but is postulated to change according to performance accomplishment (PA), social persuasion (SP), vicarious learning (VL), and emotional arousal (EA) [8]-[10].

In spite of the promise self-efficacy theory shows for understanding retention and achievement patterns in science education settings, little work has been done to understand the impact of routine classroom experiences on development of students' physics self-efficacy, and therefore potentially on their effort and success in class or retention in a major.

The purpose of this project was to explore the impact that social and pedagogical experiences in introductory physics courses have on behavioral variables. Because of the success of self-efficacy models for predicting student behaviors such as achievement and perseverance (e.g. [5], [10], [11]), this study examines the specific hypothesis that pedagogical approaches (including those suggested by PER to increase student learning) used in an introductory physics course impact the level of self-efficacy exhibited by students. Additional data was collected to help understand pathways by which such impact might place.

II. Methods and Analysis

A pilot study [12] of 321 undergraduates students in introductory physics found that both actual drop rates and "desire to drop" responses showed significant differences between traditionally taught sections, sections taught only with non-traditional pedagogies, and those including a mix of teaching approaches. Mixed sections performed best on both measures, while for the remaining sections non-traditional courses had lower actual drop rates and traditional courses showed lower desire to drop rates. Because of the demonstrated link between self-efficacy and retention, this finding that classroom factors are linked to retention and satisfaction suggests that the relationship between teaching approaches and classroom climate and self-efficacy is worthy of study.

A three part survey was developed to study this question. Besides assessing self-efficacy, the survey requests frequency of use information about various teaching approaches in the course, and demographic information.

Pedagogies chosen for inclusion in the study were those traditionally used in physics courses (lecture, quantitative and directed laboratory exercises, quantitative assignments, questions answered by the instructor, and demonstration) and others (discussion, collaborative learning, conceptual laboratory exercises and assignment questions, inquiry-based laboratories, and desk top experiments) suggested by PER and science education reform efforts. Information was also

collected about the use of electronic and audiovisual applications. Climate factors identified by Seymour [14] suggested the addition of seven questions. Four of those questions probe instructor-student climate and three questions probe student-student climate in the classroom. Reliability analysis of the climate questions led to dropping one student climate question, "Students in the class competed against each other for grades," from the current analyses. Other studies (e.g. [14], [15]) suggest that a competitive atmosphere has a negative effect on students in the class. However, analysis of the climate items in this study showed a small positive correlation between grade competition and a positive overall climate score. A detailed analysis of this climate item is clearly needed to understand this discrepancy, and is planned for the next stage of the study. With the removal of that question, a reliability coefficient of .72 was found for the climate scale.

Information was requested about students' past and current achievement (expected course grade, ACT score, past math and science classes) as well as general questions regarding age, sex, major and ethnic background. Students were also asked about outcome variables including plans for future science study, confidence in their ability to do science, and desire to drop the course.

In order to explore the pathways through which a given pedagogy might impact self-efficacy, a Sources of Self-efficacy in Science Courses scale (SOSESC) was developed, modeled on existing scales and designed to examine the sources of self-efficacy (PA, SP, VL, and EA) through typical introductory science class experiences. Analysis of data from 329 introductory chemistry students [13] and parallel analysis with this sample showed both internal consistency reliability and validity via significant associations with an established (although not course specific) measure of science/engineering self-efficacy [11] and the previously described outcome variables.

At the conclusion of the fall, 2002, semester, surveys were voluntarily completed by 377 students from nine introductory physics classes at

six campuses of the same Midwestern university system. Instructors also completed a short questionnaire including a question about the overall pedagogical strategy used. Analyses in this paper are limited to the 121 students in three first-semester calculus-based sections.

Instructors of the three calculus-based sections were male, each with four semesters of experience teaching calculus-based physics. Two of the sections (58 men and 21 women) were classified as "mixed" based on the variety of pedagogies used in the course. The remaining section (35 men and 7 women) was classified as "traditional." The classification scheme was supported by a MANOVA and follow up tests showing significant differences between students' frequency of use ratings on 10 of the 14 teaching strategies.

Differences between subjects in the mixed and traditional sections were significant on two past performance variables. Traditionally taught subjects had a slightly higher math background, and students in the mixed sections had higher ACT composite scores. Since results of this study show more positive results for mixed pedagogy classes, the math difference between subjects serves to strengthen the conclusions. Because ACT score was significantly associated with both section type and self-efficacy, it was controlled as a confounding variable in relevant analyses. For similar reasons, section size was also controlled as a confounding variable for analyses regarding climate. Neither section size nor ACT score was significantly associated with confidence change (in students' abilities to do science as a result of taking the course.)

A mixed pedagogical approach was superior to a traditional one on all variables examined: confidence change, total SOSESC self-efficacy, and classroom climate. All three variables were measured on a 5 point scale, with higher scores indicating more positive outcomes. The mean confidence score of students in the mixed sections (3.25) was significantly higher than that of those in the traditional sections (2.76) ($F_{(I,II9)} = 7.12$, p<.01).. It is interesting to note that these means show a decrease in confidence for subjects in the

traditionally taught section, as opposed to an increase in confidence for students taught with a mix of pedagogies. The mean SOSESC score for mixed-section subjects was 3.54, significantly higher per ANCOVA results ($F_{(I,106)} = 17.05$, p<.001). than the 3.06 mean found for traditional section students. ANCOVA results showed mixed section students also reported a significantly more positive classroom climate ($F_{(I,118)} = 42.81$, p<.001). The mean for mixed sections was 4.05, compared to 3.33 for traditionally taught students.

Because the above results showed significant selfefficacy differences between section types, bivariate correlations were computed to examine the relationship between specific pedagogies, classroom climate, and self-efficacy. Multiple regression analyses, controlling for the influence of ACT score and student sex, were also conducted to determine which significantly related teaching strategies uniquely predicted selfefficacy. Results of the correlation and regression analyses are summarized in Table 1. Together, these results show that among the strategies. collaborative learning, then demonstration, question & answer, and conceptual problem assignments had the greatest impact on physics self-efficacy. The teaching strategies, along with sex and ACT score, accounted for 27% (for PA) to 51% (for VL) of the variance in self-efficacy. Both student-student climate and, especially, instructor-student climate were also significantly correlated to all sources of self-efficacy.

III. Ongoing Work

Initial results indicate that some teaching strategies introduced to improve student learning are also effective for building physics self-efficacy. As in work with chemistry students [13], collaborative learning appeared especially influential. Additional analysis will shed light on related Any self-efficacy mediated link questions. between pedagogies and retention remains to be probed; sex differences in retention rates suggest that examining similarities and differences between male and female responses, as well as comparisons between students in calculus- and algebra-based courses, will help to better

understand this issue. The relationship between climate and pedagogy, and questions about how effects of one may mediate effects of the other, also remain to be explored, as does the previously mentioned question regarding competition.

Table 1. Significant Correlations between Pedagogies/Climate and Sources of Self-efficacy (p < .001 unless indicated otherwise)

	SOSESC	PA	SP	VL	$\mathbf{E}\mathbf{A}$
lecture					
q&a	.38	$.28^{a}$.34	.40	.36
discussion					
demo	.42+	$.28^{a}$.39++	.48++	.40 ⁺
collab.learn.	.33++	.25++	.32 ⁺	.34+	.31++
concept. lab	.24 ^a		.29a	.23 ^b	.22 ^b
quant. lab					
directed lab					
inquiry lab					
desktop exp	.23 ^b			.25a	$.24^{a}$
elec. applic.	.23 ^b		.23 ^b	.26ª	.24 ^b
AV present	.33		.37	.33	.33
conceptprob	.26a	.21 ^b	.25ª	$.24^{a}$.24a
quant prob					
total clim.	.52	.34	.63	.55	.44
instr. clim.	.52	.33	.63	.53	.46
stud. clim.	.28a	.21 ^b	.34	.32	.19 ^b
1					

^{*}Significant, unique predictor in multiple regression analysis.

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^{**}Strongest unique predictor among teaching strategies. a. p < .01; b. p < .05