Positive Impacts of Modeling Instruction on Self-Efficacy

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Abstract. Analysis of the impact of Modeling Instruction (MI) on the sources of self-efficacy for students in Introductory Physics 1 will be presented. We measured self-efficacy through a quantitative diagnostic (SOSESC) developed by Fencl and Scheel [1] to investigate the impact of instruction on the sources of self-efficacy in all introductory physics classes. We collected both pre- semester data and post-semester data, and evaluated the effect of the classroom by analyzing the shift (Post-Pre). At Florida International University, a Hispanic-serving institution, we find that traditional lecture classrooms negatively impact the self-efficacy of all students, while the MI courses had no impact for all students. Further, when disaggregating the data by gender and sources of self-efficacy, we find that Modeling Instruction positively impacted the Verbal Persuasion source of self-efficacy for women. This positive impact helps to explain high rates of retention for women in the MI classes.

Keywords: Self-efficacy, Modeling Instruction, Motivation
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INTRODUCTION

The confidence in one's ability to perform a task, defined to be one's self-efficacy [2], has been shown to predict a student's task persistence [3], performance in mathematics [4], and persistence through technical fields [5]. At Florida International University (FIU), we have also found that self-efficacy at the beginning of an introductory physics class predicts the likelihood of a student passing that same course [6]. Further, our findings suggest that the sources one judges self-efficacy by change with gender.

Accordingly, efforts to increase the representation of women and historically underrepresented groups in pursuing physics majors would be greatly enhanced by understanding how physics classes affect the development of self-efficacy. To this end, we present the analysis of changes in self-efficacy in the first semester introductory physics course at FIU. In order to explore both the impact of the class on the total self-efficacy, as well as how the self-efficacy develops for individuals we present data on aggregated students and self-efficacy, as well as data disaggregated by gender and sources of self-efficacy.

BACKGROUND & METHODS

At FIU many different students take introductory Physics with Calculus I. The first semester of the two-semester sequence is required for engineers, pre-health students, and science majors, as well as physics majors. Students at FIU have the option of enrolling in one of two types of introductory physics courses. The first is the traditional Lecture course, generally composed of nearly 100 students. This course meets 2 or 3 times a week for a total of 200 minutes for the lecture component with a once per week 3-hour lab component. The second option, the center of our effort to diversify the physics major, is the Modeling Instruction (MI) course. This course operates as a collaborative learning environment with thirty students in a studio-format class with integrated labs and lectures [7]. The course meets 3 times per week for approximately 2 hours, and focuses on developing and validating models through conceptual reasoning and problem solving.

The Modeling Instruction course has succeeded in improving conceptual understanding of physics, measured by the Force Concept Inventory (FCI) [8] when compared to the Lecture courses, and has also been shown to retain women and historically underrepresented groups at higher rates [9]. Nonetheless, when the FCI scores are disaggregated by gender Modeling Instruction maintains the conceptual understanding gap between men and women [9]. At FIU, we have found the odds of success, the ratio of students receiving a grade of C^- or above to those receiving a grade of D+ or lower including Drops and Withdraws, in the Modeling

Instruction classes are 6.73 times more likely than in the Lecture course despite the conceptual understand gap. Our study of self-efficacy at FIU is in part an effort to provide a mechanism for this phenomena.

In evaluating self-efficacy, Bandura emphasizes the need for specificity [10]. In other words, it would not be appropriate to ask students to rate their confidence in their ability to solve a difficult integral if one's goal is to evaluate self-efficacy of working in groups. Further, when analyzing how self-efficacy develops in an individual, it is necessary to consider the four experiential sources outlined by Bandura [10], *mastery experiences*, *vicarious learning experiences, verbal persuasion experiences, and physiological state*. In Bandura's work he theorized that *mastery experiences* would play the most important role in evaluating one's confidence to perform a task, however recent work by Zeldin and Pajares [11] suggests men and women draw on different informational experiences. Women rely primarily on *vicarious learning* and *verbal persuasion* experiences [12] when evaluating their confidence in their scientific abilities, while men predominately draw on *mastery experiences* [11].

Appropriately keeping these recommendations in mind, we evaluate self-efficacy and the experiential sources by which it develops through the Sources of Self-Efficacy in Science Courses Survey – Physics (SOSESC-P) [1]. The 33-item survey is administered twice a semester as an online diagnostic. This survey asks students to rate their confidence on a 5-point Likert scale in various situations in the physics classroom. The survey can then be disaggregated into the four sources of self-efficacy, or reported as an average of all the sources for a total self-efficacy score. The first administration, labeled as PRE results, is given within the first 3 weeks of the introductory physics class beginning. The second, or POST, administration is given within the last 3 weeks of class and finals. Students receive an e-mail asking them to follow a link to a survey that takes roughly 20 minutes of their time.

Data for this study were collected from a total of 245 matched, PRE to POST, students in three semesters, Fall 2008, Spring 2009, and Fall 2009. Demographic and course enrollment data were collected from the university database. The data include responses from 70 Modeling Instruction students, 40 female and 30 male, as well as 175 Lecture students, 65 female and 110 male. We conducted *t*-tests to compare POST scores to PRE scores for both the Modeling Instruction and the Lecture courses. Total SOSESC-P scores were compared POST to PRE for all students as an analysis of effect of course-type on all students' self-efficacy. Individual source scores were also compared POST to PRE, disaggregated by gender, to study the effect of the course on each individual source.

RESULTS

Total Self-Efficacy Shifts for All Students

We see a distinct picture emerge when comparing overall average SOSESC-P scores for all students, see Table 1. For the Lecture students, there is a significant difference between the POST and the PRE self-efficacy score, with the POST-PRE difference yielding a negative result. The Cohen's *d* effect size of -.523 suggests a medium effect from the Lecture course, with a confidence interval around it suggesting a small to medium effect. On the other hand, the Modeling Instruction course shows no significant difference between the POST and PRE scores. The confidence interval around the Cohen's *d* effect size, crossing 0.0, supports the conclusion that the Modeling Instruction course has no effect on total self-efficacy.

TABLE 1. Comparison of PRE to POST Total SOSESC-P Results by Course Type.

	Modeling Instruction (n = 70)	Lecture (n = 175)
Pre	3.838	3.565
Post	3.859	3.302
t	0.229	-6.923
p	0.819	<.0005***
Cohen's *d*	0.027	0.5233
95% CI (LL, UL)	(-0.207, 0.262)	(-0.6807, -0.365)

***p<.0005

CI = Confidence interval around Cohen's *d*, LL = Lower limit, UL = Upper limit

Shift in Self-Efficacy for Women

In order to evaluate the developmental impact of the introductory physics courses on the self-efficacy of students, we disaggregate the SOSESC-P scores by source. Further, following the results of Zeldin and Pajares [11], we also disaggregate by gender. We then examine the difference between POST and PRE for women and men separately. The top half of Table 2 shows the results for each of these sources for the

women in both the Modeling Instruction course (n = 40) and the Lecture course (n = 65).

Table 2 shows that for the Modeling Instruction (MI) courses, there is a significant difference between the POST and PRE scores only in *verbal persuasion* experiences source of self-efficacy. The positive shift paired with an effect size of .357 suggests a small and positive effect of MI on the *verbal persuasion* score of women in the course. Other sources for women in the MI course show no significant difference between the POST and PRE scores. Confidence intervals that all cross 0.0 for women in the Modeling Instruction course support the no significant effect conclusion.

The top half of Table 2 also shows the results from the Lecture course for women. These results indicate a significant negative difference between the POST and PRE scores in all of the sources of self-efficacy for women in the Lecture course. Further, the *mastery experience* and *vicarious learning* source of self-efficacy both show a medium negative effect from the Lecture course with a Cohen's *d* of -.522 and -.5489 respectively. Further contrasting with the MI result, the *verbal persuasion* source of self-efficacy in the Lecture course shows a significant negative effect, with a small effect size (Cohen's *d* = -.385).

Shift in Self-Efficacy by Sources for Men

In the bottom half of Table 2, the results from the SOSESC-P, POST and PRE are shown disaggregated by the four sources for men both in the Modeling Instruction (n = 30) and Lecture (n = 110) courses. The trend from the female scores in the Modeling Instruction class is continued in this data set. We see no significant difference in any of the four sources between the POST and PRE scores for male students in the MI course. Further, the confidence interval on all the effect sizes include or cross 0.0, supporting the claim that the MI course has no effect on the sources of self-efficacy scores for male students.

Looking at the results for the men in the Lecture Instruction course, there are significant differences between POST and PRE scores in every source of self-efficacy, as measured by the SOSESC-P. The *physiological state* source stands out as a medium effect with a Cohen's *d* of -0.526, while the *verbal persuasion* experiences source of self-efficacy shows the smallest effect with a Cohen's *d* of -0.249. The other two sources, *mastery experiences* and *vicarious learning*, both show a small negative effect from the Lecture course.

TABLE 2. Comparing PRE to POST SOSESC-P Results by Course Type, Disaggregated by Source and Gender.

	Modeling Instruction				***Lecture Instruction***			
	Mastery Experience	Vicarious Learning	Verbal Persausion	Physiological State	Mastery Experience	Vicarious Learning	Verbal Persuasion	Physiological State
				Female				
		N = 40				*N = 65*		
Pre	3.78	3.79	3.86	3.52	3.598	3.56	3.567	3.117
Post	3.84	3.81	4.09	3.55	3.27	3.24	3.35	2.82
t	0.724	0.254	2.26	0.249	-4.211	-4.425	-3.104	-3.648
p	0.474	0.801	0.030*	0.805	<.0005***	<.0005***	.003**	.001**
Cohen's *d*	0.114	0.0401	0.357	0.0394	-0.522	-0.549	-0.3850	-0.0478
95% CI (LL, UL)	(-0.197, 0.425)	(-0.270, 0.350)	(0.0349, 0.675)	(-0.271, 0.349)	(-0.780, -0.261)	(-0.808, -0.286)	(-0.636, -0.132)	(-0.706, -0.195)
				Male				
		N = 30				*N = 110*		
Pre	4.04	4.06	4.06	3.82	3.78	3.71	3.6	3.44
Post	3.91	4.00	4.11	3.74	3.52	3.49	3.45	3.11
t	-0.789	0.367	0.305	-0.443	-4.53	-3.66	-2.61	-5.51
p	0.437	0.716	0.762	0.661	<.0005***	<.0005***	.01*	<.0005***
Cohen's *d*	0.144	0.0670	0.0557	-0.0809	-0.432	-0.349	-0.249	-0.526
95% CI (LL, UL)	(-0.217, 0.513)	(-0.292, 0.425)	(-0.303, 0.413)	(-0.2783, 0.439)	(-0.627, -0.236)	(-0.541, -0.156)	(-0.438, -0.0582)	(-0.724, -0.325)

*p<.05, **p<.005, ***p<.0005

CI = Confidence interval on Cohen's d, LL = Lower limit, UL = Upper limit

DISCUSSION

Effect of Course Type on Self-Efficacy

As described earlier in this paper, self-efficacy as a construct, has been linked to several positive factors for students such as persistence and performance [3-5]. Thus, as educators we would like to see our students positively impacted in the area of self-efficacy. However, how do we view a positive impact? In this study the Lecture course showed a negative effect on self-efficacy from the beginning of the semester to the end, while in the Modeling Instruction course we see no significant effect on total self-efficacy from PRE to POST. Our results coincide with earlier results presented by Fencl and Scheel [13] suggesting that the traditional lecture classroom resulted in negative effects on self-efficacy while a class with a reformed pedagogy showed no significant impact on total self-efficacy. These combined results suggest that a positive effect on self-efficacy may actually reside in a no net change result.

When disaggregating the SOSESC-P scores by source type, we gain a deeper insight into how the two different classroom formats affect self-efficacy of students. The MI course implements many of the pedagogical techniques common to reformed classrooms in that it centers on group work and informal individualized interaction between student and instructor. The limitations of this study do not allow us to make conclusive claims as to what features of the MI course impact self-efficacy, yet considering the key features of the course provides insight into how self-efficacy may develop within this course.

In contrast to the traditional Lecture classroom, the MI class provides frequent opportunities for *vicarious learning* experiences in the regular group work of the integrated lab activities. The course is also replete with formative assessment strategies as well as traditional homework and mid-term tests, thus providing further opportunities for positive *mastery experiences*. In other work, we have shown that the *physiological state* source is highly correlated with the *mastery experience* source [6], thus it is no surprise that when a student has positive *mastery experience* the *physiological state* also follows suit. Lastly, the interactions in the MI classroom between students and instructors provide for many positive *verbal persuasion* experiences, though it is interesting that even in the Lecture format course this source shows the least negative effect. This is consistent with Bandura's theory that the *verbal persuasion* source has the greatest impact on someone who already has a sense of self-efficacy.

Source Shifts in Self-Efficacy for Women

The sources of self-efficacy are important as they tell us about particular experience that affect the development of self-efficacy. Earlier studies show that men and women draw on different sources of self-efficacy with women relying on both the *vicarious learning* and *verbal persuasion* experiences [6, 12]. The data from this study suggest that the traditional Lecture classes negatively affect all of the sources for the students, regardless of gender. For women in particular, the Lecture class shows a medium negative effect on the *vicarious learning* source of self-efficacy, and a small negative effect on the *verbal persuasion* source. Contrasting with these results, the only positive effect seen in this study appears in the *verbal persuasion* experiences source of self-efficacy for women in the Modeling Instruction course. Combining these results with the understood relationship between self-efficacy and retention, this *verbal persuasion* source of self-efficacy may be part of the explanation for why women have a much higher odds of success in the Modeling Instruction course than they do in the Lecture format course.

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