# Impact of the FIU PhysTEC Reform of Introductory Physics Labs

Leanne Wells, Ramona Valenzuela, Eric Brewe, Laird Kramer, George O'Brien, Edgardo Zamalloa

Florida International University
Department of Physics and Department of Curriculum and Instruction
Miami, FL 33199

Abstract. We report results from a study of pre and post assessments of students enrolled in reformed and non-reformed introductory physics laboratories. This study assesses the impact of Florida International University's (FIU) PhysTEC (Physics Teacher Education Coalition) reform of introductory physics labs. Prospective pre-service teachers were trained and placed in six lab sections serving as undergraduate Learning Assistants (LAs) and implementing tutorial-based curriculum. LAs facilitated epistemological discussions designed to challenge and then refine student understanding of physics concepts. Students completed the Force Concept Inventory (FCI) [1], the Maryland Physics Expectation Survey (MPEX 2) [2], and common exam questions embedded in the exams for their physics classes. We find significant differences in normalized gain on the FCI and common exam questions in favor of students in the reformed labs. There was no significant difference in pre and post MPEX 2 scores for reformed lab students, generally agreed to be a positive outcome.

### **INTRODUCTION**

Due largely to national shortages of qualified science teachers and poor access to educational opportunities, there is general cause for concern in the United States regarding persistence rates and success in the fields of science and mathematics. Even more striking is the loss of potential contributions to science as students from Hispanic and African descents persist in these fields at a rate disproportionate to their presence in the overall population [3].

In order to reduce drop, failure, and withdrawal (DFW) rates and improve conceptual understanding of physics in undergraduate physics courses, several groups have implemented inquiry-based tutorials or labs designed to enhance students' ability to reflect upon and therefore clarify their understanding of physics as well as their epistemological framework [4,5,6,7]. Other efforts include peer-teaching and peer-study models [8,9]. At the university level, an examination of reform efforts at institutions with a majority population of underrepresented groups reveals a deficit in the literature. Florida International University's population of 59% Hispanic and 13%

Black provides the opportunity to explore the efficacy of reform efforts on underrepresented groups [10].

# PHYSTEC LAB REFORM AT FIU

Florida International University's (FIU) efforts at laboratory reform are an integral part of its work as a Physics Teacher Education Coalition (PhysTEC) Primary Partner Institution. PhysTEC is a partnership of the American Physical Society, the American Institute of Physics, and the American Association of Physics Teachers with a goal of improving and promoting the education of future physics teachers. FIU is one of twelve Primary Partner Institutions nationwide and is in its first year of operation. FIU's Physics Department and College of Education faculty are committed to reforming our physics teacher education program by combining our ongoing inquirybased reform efforts with the strengths and successes of PhysTEC to make a substantial impact on physics education in diverse South Florida.

Following the University of Colorado at Boulder model, FIU is developing an integrated, multilevel preservice program that recruits high quality students to become Learning Assistants (LAs), then places these LAs in early field experiences to give them the best training available, and provide a supportive mentoring environment in which to develop and hone their teaching skills [8,11].

FIU has adapted and implemented a tutorial-based curriculum in the introductory physics laboratories complementing a traditional lecture component. Tutorials and instructor-led demonstrations designed by the Physics Education Research Group at Maryland [7] were combined and organized to align with the sequence of instruction at FIU.

#### LAB REFORM IMPLEMENTATION

Each of the six labs implementing the tutorial-based reform were led by a graduate Teaching Assistant (TA) and 1-2 undergraduate LAs. Students in the reformed labs worked in groups and the TAs and LAs acted as facilitators of learning. The tutorials require students to make predictions individually, come to a consensus as a group, perform an investigation or thought experiment, and then reconcile those results with the consensus. Groups were directed to consult with their instructors at key points throughout the lab.

In order to make the use of the tutorials effective, the TAs and LAs trained weekly with project faculty and teacher-in-residence clarifying physics concepts as well as discussing student conceptions and pedagogy for facilitating learning. The LAs were also enrolled in *Seminar in Physics Education*, a science education class modeled after a course developed at the University of Colorado [11]. The course involved reading and discussing educational research articles, and emphasized implementations of research findings in the field experiences that included the reformed labs.

During these reformed labs, the LAs main objectives were to check for understanding of specific physics concepts at the checkpoints built into the tutorials and to encourage and facilitate the epistemological and metacognitive development of the students. LAs practiced discourse and Socratic questioning techniques suggested in the training sessions or the seminar course. They also used purposefully designed demonstrations to expose and challenge naïve conceptions.

This paper presents an assessment of the effects of the reformed lab experience on introductory physics students' conceptual understanding and attitudes and beliefs about physics.

#### **METHODS**

Four hundred and sixty-seven students were enrolled in FIU's Introductory Physics I with and without calculus traditional lecture courses during the Spring 2008 term. Roughly two thirds of these students enrolled in fourteen lab sections. The labs included students from both the calculus and algebra-based courses. Six of the fourteen introductory physics lab sections were chosen for the reform treatment. The remaining lab sections followed a traditional MBL protocol. Twenty-four students were in each of the labs. Students enrolled in lab sections independently of lecture sections and, upon enrolling, had no indication of which sections were reformed and which were traditional MBL.

Several diagnostics were used to evaluate the impact of the curricular reforms on student conceptual understanding of and attitudes about physics. To gauge student understanding of Newtonian force and motion, pre and post assessments of the Force Concept Inventory (FCI) were administered to all Physics I lecture courses.

Table 1. Conceptual Common Exam Problem Example: Elevator Problem [7].

#### Context of Problem

Leigh boards the Twilight Zone Tower of Terror ride at Disney's California Adventure. Along with 9 other people, she steps into the elevator of the "haunted hotel." It then proceeds to travel to the top of the hotel being attached only by an elevator cable! At the top of the elevator shaft, 11 stories above ground, the elevator is released and is in free fall before brakes are applied, which bring the elevator to a stop.

#### Question

Although the passengers are strapped securely, Leigh starts screaming during the free-fall part of the ride. In the space below draw an arrow to represent the direction of the net force on Leigh during that part of the ride. Is the magnitude of the net force on Leigh *greater than, less than,* or *equal to* her weight? If the net force is zero, state so explicitly. Explain your answer.

Five professors were provided with and selected common exam questions (see Table 1) to embed in their second exam. These questions were based on items in the materials accompanying the Maryland tutorials; neither students in the reformed or non-reformed labs were exposed to them prior to the

second exam. These free response conceptual exam questions probed common errors in understanding force and motion. Two graders blindly scored student responses to these questions based on a common rubric. The rubric was created, reviewed, and revised to serve as an indicator of evidence of student understanding of foundation concepts. It was not used for assigning grades. Raters met to reconcile differences in scores greater than ten percent. Scores within the ten percent agreement range were averaged to obtain a single score.

Lastly, pre and post assessments of the Maryland Physics Expectation Survey 2 (MPEX 2) were administered to reformed lab students [2]. This survey measures students' attitudes and beliefs about physics and learning physics. Within the survey, clusters of questions characterize three main epistemological beliefs in introductory physics: *coherence*, *concepts*, *independence* [12]. Elby describes another five subclusters [2].

Two-sample t-tests were used to compare student learning gains on the FCI and performance on common exam questions. A matched t-test compares differences in favorability scores on pre and post MPEX 2 surveys.

# RESULTS AND ANALYSIS

The results of FCI pre- and posttests for the different groups appear in Table 2. Pretest scores for the two groups were not significantly different (t-stat = 0.592, p-value = 0.555). There is a significant difference in posttest scores for students in reformed and non-reformed labs (t-stat 3.58, p-value < 0.001). There is a significant difference in pretest/ posttest normalized gains for students in reformed and non-reformed labs (t-stat 3.91, p-value < 0.001).

Table 2. Data for the Force Concept Inventory.

			FCI	
		% pre	% post	average
		class	class	normalized
		average	average	gain
Group	N	<si></si>	<sf></sf>	<g>*</g>
reformed lab	38	25	50	0.33
non-reformed lab	63	24	37	0.18

A two-sample t-test assuming equal variances for pre FCI scores compares learning gains between different groups.

Analysis of the scores on common exam questions indicates that students in reformed labs (n = 29) scored

14% higher than students not in reformed labs (n = 198) (p-value < 0.001). Tests for homoscedasticity and normality were satisfied.

Figure 1 presents percent favorable and unfavorable pre and post results for the MPEX 2 coherence, concepts, and independence clusters. Also, for each cluster, a favorability score, % favorable - % unfavorable, was calculated for each student. This score accounts for decreases in unfavorable responses as well as increases in favorable responses. Matched t-test analyses of pre and post favorability scores show no significant differences in any of the three main clusters or the five subclusters.

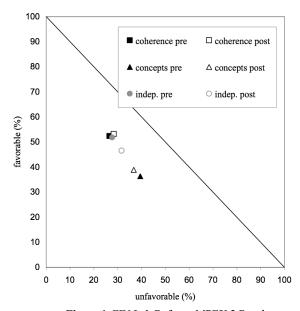


Figure 1. FIU Lab Reform: MPEX 2 Results.

# DISCUSSION AND FUTURE RESEARCH

Significant gains in FCI for reformed lab students versus non-reformed lab students show that the combination of the modified tutorials and the addition of LAs to the lab environment is a successful means of improving student conceptual understanding of Newtonian force and motion. We believe that the active engagement of reformed lab students with LAs in peer-to-peer discussions about the conceptual content allows the students to evaluate and then modify their understanding to more closely match accepted scientific understanding. This better enables students to identify concepts with underlying physical phenomena.

 $<sup>*&</sup>lt;g> = (\%<S_i>-\%<S_i>) / (100-\%<S_i>) [13]$ 

Although the FCI posttest class average for reformed students is less than 60%, which is considered the entry threshold necessary for Newtonian problem solving [1], a normalized gain of 33% is moderate [13] and comparable to results for reform efforts with underrepresented groups found at Chicago State University [14]. To strengthen our results and allow for comparisons by group, especially gender and ethnicity, we intend to double the number of sections for the reform treatment.

This study also examined another aspect of student performance on conceptual tasks: free response conceptual common exam questions. A 14% significant difference in the mean scores on the common exam questions indicates that the reformed labs may better prepare students to apply physics concepts to unfamiliar problems. It may be that because the tutorials required students to make predictions, come to a consensus on those predictions, and then evaluate the validity of those predictions, that the students became more confident and adept at constructing answers to questions about physics. However, a more detailed and careful exploration of the lab reform effects on students' problem solving ability is necessary.

Although there were no significant positive changes in favorability scores for any of the three main epistemological characteristics describing student attitudes and beliefs about physics, it is generally accepted that this is a positive result as traditional and even some reform experiences result in negative shifts [15]. The reform treatment did not result in students adopting more novice-like, as opposed to expert-like, beliefs. Additionally, previous research has indicated that student attitudes and beliefs play a significant role in conceptual understanding of physics [16]. Taking this into consideration along with the FCI and common exam question results, we believe that the lab reform efforts at FIU do not negatively impact student attitudes and beliefs, and that this may be an important factor in the learning gains of students in the reformed lab sections.

The lab reform has two components: implementing tutorials and staffing by LAs. Quantitative analysis shows the FIU lab reform is successful in improving student conceptual understanding and does not adversely affect student attitudes and beliefs. We are confident that both the inclusion of tutorials and the presence of well-trained Learning Assistants contribute to the reform's success. However, the influence of either part of the reform cannot be isolated. For further study, the number of reform lab sections will be expanded. Lecturer, TA, and LA

effects as well as student grades and DFW rates in the lecture warrant investigation. The effect of the experience on the undergraduate Learning Assistants also should not be excluded from study.

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