

# Preliminary Results of Gender Equity Variations in a Large Active-Learning Introductory Physics Course Due to Laboratory Activity Instructions

Mark L. McKinnon and Wendell H. Potter

*Physics Education Research Group, Department of Physics, University of California at Davis,  
One Shields Avenue, Davis, CA 95616*

**Abstract.** In the UC Davis introductory physics course for life science majors, variations in lab activity instructions were introduced to investigate their influence on gender performance differences. Systematic instructions were compared to unguided, open-ended instructions. On preliminary examination, the performance difference between females and males was unaffected by the different instructions. However, there is some evidence that the open-ended instructions did increase students' conceptual understanding in general.

## INTRODUCTION

An important consideration of improving pedagogical styles is to reduce gender bias and performance differences while increasing all students' conceptual understanding of a subject. In an active learning setting, we utilized dissimilar sets of laboratory activity instructions to determine whether instructions that are more open-ended would improve gender equity. If the data shows positive results, the ability to increase retained understanding and decrease gender inequities through the utilization of open-ended instructions would prove a benefit to students and instructors alike.

Much of the research in gender differences has focused on performance on a variety of tests [1]. Differences in cognitive tests that once appeared to demonstrate differences between males and females have diminished considerably, leading many researchers to conclude that cognitive differences do not exist [2,3]. However, males still outperform females in physics and science courses [4,5]. What is not clear is whether the concepts or the methods with which these concepts are taught generated these gender performance differences. Several members of the UC Davis Physics Education Research Group have turned their attention to the differences in gender performance [6]. We have begun to examine the

specific wording and structure of activity instructions given to students in the laboratory setting.

Current research indicates that active learning creates a greater understanding among students in science courses than does a passive, lecture-oriented curriculum [7, 8, 9]. In 1996, UC Davis implemented a major restructuring of the introductory physics course for life science majors. We replaced a traditional introductory physics course (a three-quarter sequence labeled 5A, 5B, & 5C) with a cooperative approach that motivates students to become more active in their learning. In this new course (called 7A, 7B, & 7C), students work in small groups to answer questions about an observed phenomenon. Instead of three hours of lecture and 2 1/2 hours of laboratory per week, the students attend a single 80-minute lecture – where they are usually assessed for understanding – and two 2 1/2 hour discussion/laboratories – where they perform experiments and discuss how to analyze and describe what they saw. The lab activities are designed to motivate the student to actively construct new models of a variety of physical phenomena [10, 11].

Two years ago, at the 2002 AAPT National Meeting and PER conference, we presented evidence that demonstrated a tremendous improvement in gender equity when comparing the Physics 7 sequence

to the Physics 5 sequence [12]. However, while gender equity has been improved throughout the entire sequence of Physics 7, among the three quarters, inequality still exists. Table 1 shows that the distributions of course grades for males and females are nearly aligned in Physics 7A. The distributions for 7B and 7C are less so.

**Table 1. Gender Performance Differences in Three Quarters of UC Davis Introductory Physics for Life Science Majors (Physics 7A, 7B, & 7C)**

Course	Gender	N	Mean <sup>a</sup>	Std. Dev.
		t-test <sup>c,d</sup>	Diff. <sup>b,c</sup>	Std. Error <sup>c,d</sup>
7A	Female	4187	2.459	0.553
	Male	2449	2.556	0.557
	Compare	-6.861	<b>-0.097</b>	0.014
7B	Female	3563	2.424	0.590
	Male	2058	2.617	0.661
	Compare	-10.909	<b>-0.192</b>	0.018
7C	Female	2724	2.443	0.549
	Male	1625	2.583	0.590
	Compare	-7.805	<b>-0.141</b>	0.018

Notes: a - Mean grade earned based on 0-4.5 scale.  
 b - Diff. is mean difference for (females – males)  
 c - Equal variances were not assumed  
 d - Significance <10<sup>-10</sup>

The gender performance differences may result from dealing with particular concepts or due to variations in pedagogy. Instructors would implement variations in the laboratory activities and assessment tools for each course. One of the noticeable differences between the 7A and 7C lab activities was that the instructions for 7C activities were much more formulaic. While the lab activities still required interaction among the students, the instructions were often systematic and could be performed without much discussion. Our study was to determine if these instructions had an effect on gender differences in understanding the exhibited concept. We generated several activity instructions that required the students to pursue the same conceptual understanding without engaging in a step-by-step format. For example, one activity asks the students to determine what parameters of a pendulum affect its period. The original (*Formulaic*) set of instructions listed the parameters and instructed the students to make a pendulum with a specific length, mass, and amplitude and test specific changes. The *Open-ended* activity merely presents the students with a string and mass and asks them to determine the parameters of a pendulum and find which affect period and what effect they have. The students depend on their group members to help complete the assignment. Our working thesis was that the open-ended instructions would foster greater

communication within the lab groups. We hoped that this, in turn, would encourage greater gender equity by decreasing the performance difference between females and males.

## METHOD

During the spring quarter of 2004, 471 students completed the Physics 7C course. One group of 185 students received the Formulaic instructions. Another group of 197 students received the Open-ended instructions. The remaining 89 students received a mixture of Open-ended and Formulaic instructions. This arrangement lasted for the first eight of the eighteen class meetings. During the remaining meetings, all students received the same set of instructions, which were a mixture of Open-ended and Formulaic instructions. The physical phenomena discussed in the experimental classes included SHO, 1-D, 2-D, and 3-D waves, and superposition of waves. Phenomena discussed during the remainder of the quarter included nuclear forces and decay, electromagnetism, and optics. All students were assessed concurrently and with identical assessment tools during the lectures. Assessment for both groups included several short-answer questions that were conceptual, graphical, algebraic or computational in nature.

### Sample Set Comments

The student body at UC Davis reflects a socio-economic background that is predominantly middle to upper class. The student body is under-represented with African-Americans and Hispanics. There is an over-representation of Asian and Asian-American students. In this preliminary analysis, ethnic origins were ignored. Nearly all students who take the Physics 7 sequence are Life Science majors, usually pre-med or pre-vet. This population has a far larger number of females than males. In our sample, we had 293 females and 168 males.

### Data Analysis

There were four quizzes and three questions on the final that related to the experimental activities. For preliminary analysis, these seven scores were given even weight and averaged. Scores are given on a 4.5 scale (e.g. 4.13 to 4.5 earns an A+). An “acceptable” answer for a particular question earns at least 2.5, with

more points given to a more complete, thorough or accurate answer. This score became the dependent variable. The students' course grades for Physics 7A and Physics 7B were covariates and gender and lab group were the factors. We performed the Univariate ANCOVA of this data with SPSS. We eliminated the data for all students (24 students) who were in our section to minimize bias. We also eliminated the data for any student for which we did not have both Physics 7A and 7B grades. Finally, we eliminated students who missed three or more of the assessments. The final numbers of students in each group were 142 in the Formulaic group and 167 in the Open-ended group.

**Table 2. Estimated Marginal Means of Quiz Scores by Lab Group & Gender**

Lab Group	Gender	Mean <sup>a</sup>	Std. Error	95% Confidence Interval	
Formulaic	Female	2.573	0.047	2.481	2.666
	Male	2.549	0.065	2.421	2.676
Open-Ended	Female	2.595	0.042	2.512	2.678
	Male	2.650	0.063	2.526	2.775

Note: a - Covariates are evaluated at the following:

7A Grade = 2.718

7B Grade = 3.230

**Table 3. Univariate Analysis of Covariance: Tests of Between-Subjects Effects on Quiz Scores**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	95.367 <sup>a</sup>	5	19.073	93.559	0.000
Intercept	2.072	1	2.072	10.165	0.002
7A Grade	16.149	1	16.149	79.214	0.000
7B Grade	14.409	1	14.409	70.677	0.000
<b>Lab Group</b>	0.256	1	0.256	1.255	<b>0.264</b>
<b>Gender</b>	0.015	1	0.015	0.075	<b>0.784</b>
<b>Lab Group &amp; Gender</b>	0.108	1	0.108	0.530	<b>0.467</b>
Error	61.771	303	0.204		
Total	2230.676	309			

Note: a -  $R^2 = .607$  (Adjusted  $R^2 = .600$ )

As Table 2 shows, the estimated means due to the covariates, the grades from the first two quarters of the course, are very close. The confidence intervals overlap considerably. As further evidence, the value of the significance of the F-statistic in the ANCOVA shown in Table 3 is very high. This demonstrates that the lab activity instruction had very little effect on the differences in performance due to gender. There seemed to be a quite low level of confidence (sig. = 0.264) that the open-ended instructions improved all students' understanding. However, the null hypothesis

that the type of activity instruction did not affect gender performance could not be discarded.

## DISCUSSION

The results tentatively indicate that while overall understanding increased, the degree of guidance within the activity instructions had no effect on the performance difference between genders. However, this is only a preliminary look at this data. There are a number of finer points to analyze. A natural next step is to separate the assessment questions into categories (conceptual, graphical interpretation, algebraic and computational). We would like to determine whether the gender performance difference in each category saw the same results. The ethnic breakdown of the student sample might present different results since gender differences do not necessarily cross ethnic lines [13, 14]. Additionally, using a different covariate (e.g. overall GPA) might provide greater accuracy than the 7A and 7B grades, especially if the earlier physics grades disguise a gender inequity. We plan to test the results for repeatability in fall quarter, 2004, in another Physics 7C class. During this second phase of the study, we plan to interview several students from the two groups to capture insight from the participants.

A question that has continued to percolate throughout the running of this experiment is whether the variation in the activities is great enough. Both sets of activities give the student a definite end-point to the activity with the open-ended activity instructions eliminating systematic instructions of how to attain the given end-point. The next step would be to somewhat obscure the end-point itself. This obfuscation might affect the gender performance difference by requiring the students in each lab group to establish greater communication. The concern lies in maintaining overall understanding. There is much to study and there are multiple methods that can be used to analyze these issues.

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