

Introductory Physics Gender Gaps: Pre- and Post-Studio Transition

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Abstract. Prior work has characterized the gender gaps present in college-level introductory physics courses. Such work has also shown that research-based interactive engagement techniques can reduce or eliminate these gender gaps. In this paper, we study the gender gaps (and lack thereof) in the introductory calculus-based electricity and magnetism course at the Colorado School of Mines. We present eight semesters' worth of data, totaling 2577 students, with four semesters preceding a transition to Studio physics, and four following. We examine gender gaps in course grades, DFW (D grade, fail, or withdrawal) rates, and normalized gains on the Conceptual Survey of Electricity and Magnetism (CSEM), and consider factors such as student ACT scores and grades in prior math classes. We find little or no gap in male/female course grades and DFW rates, but substantial gaps in CSEM gains that are reduced somewhat by the transition to Studio physics.

Keywords: Studio Physics, Gender Gaps, Curricular Transition.

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INTRODUCTION

The gender gaps in science, involving both representation and performance, are well-known (see, for example, [1]). Some groups [2-4] have considered the possibility that interactive engagement tools, including but not limited to Peer Instruction [5] and Tutorials [6], can close gender performance gaps in physics courses, hopefully leading to smaller representation gaps. These groups have had mixed success, but the overall tendency is for more interactive classrooms to result in smaller gender performance gaps [3].

The Colorado School of Mines (CSM) is a small (~4000 undergraduates) predominantly science and engineering college. The physics department is relatively large, with approximately 250 undergraduate majors. Women make up between 20 and 25% of the overall undergraduate population. Like many institutions, CSM is interested in improving both recruitment and retention of women. An important step towards this goal is to identify, explain, and attempt to mitigate any performance gaps that may exist between men and women. Physics with calculus 100 (mechanics) and 200 (E&M) are part of the common core at CSM – all students take these courses, regardless of major, making successes or failures in these courses of particular significance. Recognizing this fact, the institution has built a dedicated Studio room, and Physics 100 and 200 have implemented Studio Physics [7-9]. The Physics 200 transition occurred in

the fall of 2007, leading to what Lorenzo et. al. [2] describe as a fully interactive course (IE2). Before this transition, Physics 200 had traditional labs and recitations, but used clickers with a Peer Instruction model in lecture, which Lorenzo et. al. describe as a partially interactive course (IE1). No strictly traditional introductory courses have been taught at CSM for several years, and none shall be analyzed here.

In this preliminary study, we have two major goals. First, we will characterize and attempt to explain the gender gaps that exist in Physics 200, both before and after the transition to Studio physics. This represents a unique perspective as, to our knowledge, little work has been done involving gender gaps in E&M and/or in Studio physics (see some exceptions in Ref. 3, 10, 11). Second, we will investigate the hypothesis that interactive engagement techniques reduce gender gaps, and that more interactive courses lead to greater reductions.

COURSE AND METHODS

Since Studio Physics 200 is part of the CSM common core, we see a broader than usual population for a physics-with-calculus E&M course, including such majors as mining, geology, and economics. There are typically 300-450 students enrolled each semester. The course was 22% female during the non-Studio semesters studied (Fall 2005 – Spring 2007), and also 22% female during the Studio semesters studied (Fall 2007 – Spring 2009).

TABLE 1. Gender gaps in Physics 200. All <M-F> figures show male averages (in percent) minus female averages. p-values are shown in parentheses. The final row shows the statistical significance of the difference between non-Studio and Studio gender gaps, when comparisons are useful. Population size, N, ranges from ~250 (female non-Studio population) to ~1000 (male Studio population). Course grades are out of 100%.

	DFW Rate	Course Grade (C or better)	CSEM <g>	CSEM Pretest	CSEM Posttest
<M-F> non-Studio	-2.4% (p=0.4)	2.1% (<0.01)	0.12 (<0.0001)	7.1% (<0.0001)	13% (<0.0001)
<M-F> Studio	-0.4% (p > 0.8)	1.2% (0.03)	0.08 (<0.0001)	4.2% (<0.0001)	8.3% (<0.0001)
p non-Studio vs. Studio	----	p = 0.12	p = 0.01	p = 0.001	p = 0.001

CSM uses a hybrid Studio/lecture model. Each student attends two weekly one-hour lectures and also attends two two-hour Studio sessions. The course is described in detail elsewhere [9]. One point is worth noting: A fair portion of the Physics 200 curriculum did not change significantly when the transition to Studio was made. The curriculum is still being redeveloped to fully match the new learning environment; we therefore expect less-substantial (but still significant) differences between the Studio and non-Studio courses than if the curriculum had been completely redesigned.

The faculty assignments for Physics 200 have been remarkably stable over the study period. One senior lecturer has been involved in six of the eight semesters studied, with the remaining two (Fa 08 and Sp 09) being taught by the same pair of faculty, each strongly mentored by said senior lecturer.

There are a great many measures by which we can compare male and female populations in our courses. For the sake of brevity, we will present what we consider to be the most informative. All but one of the semesters studied gave the Conceptual Survey of Electricity and Magnetism (CSEM) [12] as a pre- and post-test. The CSEM provides us a uniform instrument for comparing across semesters and potentially with other institutions. Since this study is motivated in part by a desire to improve retention of women, course grades are also very relevant. One must be cautious in analyzing course grades since the standards, instructors, and curricula may shift, but in this case the curriculum and instructors are fairly constant over the study period, and in any event, we will only be comparing the *relative* performances of men and women in the class. We will present data on both the DFW rate (the fraction of the course receiving a D, an F, or withdrawing) and the average overall course scores for students receiving grades above a D. Since gender gaps may be a function of student preparation, we will summarize student ACT scores and grades in prerequisite math courses. We

do not currently have access to high school physics data for these students.

All statistical results shown are from either a two-tailed z-test or a two-tailed binomial proportion test, as appropriate.

DATA

Table 1 shows data on the gender gaps in Physics 200. All data are from taking the difference of average male and female percent scores. For example, the DFW non-Studio entry shows that the male DFW rate was 2.4% less than the female DFW rate. We do not consider absolute scores in this paper. The data show that women are statistically no more likely to receive a D, an F, or withdraw from the course than men, and that this is the case in both non-Studio and Studio courses. The “Course Grade” column shows the difference in average course grades (out of 100%) for men and women that receive at least a C (those students not covered by the DFW rate). These data show statistically significant male/female differences in both non-Studio and Studio courses. Studio physics shows a smaller gender gap, but the Studio vs. non-Studio difference is not significant. It is also worth noting that the gender gaps that do exist are on the order of 1-2%, and might not be considered educationally significant even if they are statistically significant.

The final three columns in Table 1 describe gaps in the CSEM. These are large and significant, with women lagging men in CSEM normalized gain by 0.12 in non-Studio courses, and 0.08 in Studio courses. Absolute CSEM gains in this course are typically ~0.40. The change in gender gap from non-Studio to Studio is significant with a p = 0.01. There also exist gaps in the CSEM pre- and post-test scores. Note that the gap in the pretest score dropped by ~3% from non-Studio (7.1%) to Studio (4.2%): Women in recent semesters are coming into the class performing slightly better on the CSEM (relatively) than in

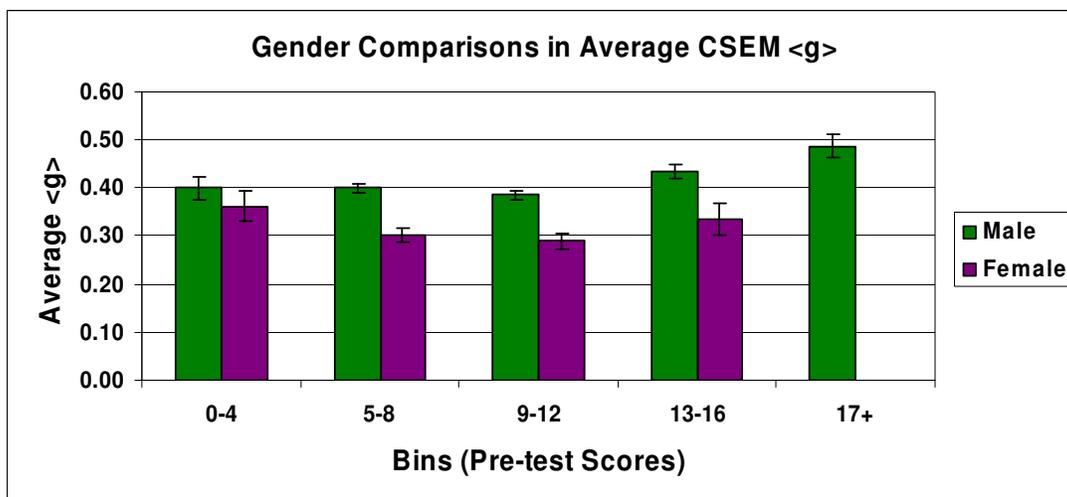


FIGURE 1. CSEM normalized gain scores binned by pretest score. The results here reflect the overall number of students with pre- and post-CSEM scores (M = 1348, F = 377). There were too few women that scored 17+ on the pretest to allow a meaningful comparison. Error bars show the standard errors of the means.

earlier semesters (3% corresponds to about one CSEM question). Note also that the gender gap in the posttest score dropped by ~5% from non-Studio (13%) to Studio (8.3%).

Although the gender gaps seem to be shrinking after our Studio transition, we need to consider the possibility that the gender gaps in CSEM gain are related to factors external to the course. While CSM has no standardized math or science placement exams, we do have access to the ACT scores for most students, as well as their grades in differential and integral calculus (calculus 111 and 112, respectively). These are shown in Table 2. None of these scores vary significantly over the study period, so we show only the overall average. N is 300-1200 for each case.

The average ACT composite scores for men and women in the study period were 27.5 and 27.7. The gap is not significant. The ACT math sub-scores for men and women were 29.1 and 28.4 respectively. Men showed a slight (~1 point on a 36-point scale) advantage in science sub-scores, while women showed a similarly slight advantage in the English and reading sub-scores. In CSM calculus classes, men and women have average grades of 2.95 vs. 3.07 (on a 4-point scale) in Calculus 111, and 2.81 vs. 2.83 in Calculus 112. We offer the calculus data cautiously. CSM Calculus 111 and 112 courses are taught by adjuncts and while students take common exams, there is potential for great variation from course to course. In addition, many students receive transfer or advanced placement credit for calculus. With these confounding factors, we perform no statistical tests on these data. That said, these grades are the best available indicators of student

performance in mathematics at CSM, and suggest that, at the least, women do no worse than men in their calculus classes.

With minimal gender differences present in ACT scores and math grades, we turn to the possible effects of incoming physics content knowledge. Men do show a small advantage in CSEM pre-scores, and pre-test scores have been shown to predict gains on mechanics exams [13]. Figure 1 shows CSEM normalized gains for men and women as a function of their pre-test scores, divided into various bins. Bin 1 includes pre-test scores from 0 – 4, bin 2 from 5 – 8, bin 3 from 9 – 12, bin 4 from 13 – 16, and bin 5 from 17 onward. There were too few women to make a meaningful data point in bin 5, so we omit that point for women. Approximately one hundred male students are in bin 5, and these students have the highest <g> of all. It is the case that a portion of the overall gender gap is attributable to this population imbalance (the fact that no women come in with extremely high pre-test scores). However, examination of the other bins shows that gender gaps are present even when pre-test scores are controlled for; the CSEM gaps are therefore not solely a result of more men coming in with high pre-test scores.

DISCUSSION AND CONCLUSION

This paper presents two significant results. First, we find that CSM Studio Physics 200 courses have no significant gender gaps in terms of DFW rates and course grades. In spite of this, men show a substantial advantage in normalized CSEM pre-test scores, post-test scores, and normalized gains. A full breakdown

TABLE 2. Male and female ACT composite scores and math sub-scores (out of a 36 point scale) for students taking Physics 200 during the study period. There were no significant differences between the scores for Studio and non-Studio classes. Also shown are the average grades for both groups in differential and integral calculus, on a four-point scale.

	ACT Scores		Grades	
	Composite	Math	Calculus 111	Calculus 112
Male	27.5	29.1	2.95	2.81
Female	27.7	28.4	3.07	2.83

of the course grades (not shown) shows that men do slightly better on the multiple choice tests (~2%), while women do slightly better on homework and Studios (also ~2%), consistent with Ref. 3. Since all components of the course are weighted heavily towards mathematical tasks, it would appear that women are performing equally on such tasks, but are performing worse on the conceptual tasks present on the CSEM, a result that some may find unexpected.

The second result is that the data are *consistent* with the conjecture that the more interactive a course is, the smaller the gender gaps will be [2,3]. Since some of the gender gaps (course grade, DFW rate) are small or non-existent even before implementation of the Studio, we cannot consider this to be a strong test of the interactivity conjecture. We do see a significant narrowing of the gap in CSEM gains, though the bulk of the gap remains. We cannot attribute this gap entirely to student preparation: Gender gaps on the ACT and calculus classes are minor at best, and a binning of the CSEM results by pre-test scores shows that gender gaps are present in nearly all segments of the population. It seems that the course, despite introducing no gaps in grades or DFW rates, is affecting men and women differentially in terms of conceptual development. Since the in-progress curriculum redesign targets conceptual growth, it will be important to determine how new materials are received by both men and women.

The analysis in this short paper is rather cursory. A future, full-length paper will include more complete statistical analysis to explain in more detail the persistent CSEM gender gaps. On a related topic, we have anecdotal reports suggesting that significant gender gaps re-emerge in majors-only courses in our program. Longitudinal work is in progress to investigate this possibility.

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